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Rev. John Gardham Reed, Burlington Manse, South Road, Saffron Walden, Essex ; and

Richard Frind Roberts, Westcroft, Warlingham, Surrey,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Frederick Joseph William Crowe, Organist of Chichester Cathedral, Marsden, Chichester (proposed by J. A. Greenwood) ;

Thomas Edward Heath, 53 Park Place, Cardiff (proposed by J. Larmor) ;

Samuel Thomas Johnson, Melrose, Bridport, Dorset (proposed by H. H. Turner) ;

George Tyrrell McCaw, B.Sc., Geodetic Survey, North Eastern Rhodesia, South Africa (proposed by S. S. Hough) ; and

Percy Alfred Talbot, B.A., F.R.G.S , F.A.I., Royal Societies' Club, St. James's Street, S.W. (proposed by E. A. Reeves).

Sixty three presents were announced as having been received since the last meeting, including, amongst others :—

T. E. Heath, Our Stellar Universe, presented by the author ; Observatoire de Bordeaux, Catalogue photographique du Ciel (coordonnées rectilignes), tome i., presented by the French Government.

Astrographic Chart of the Heavens :—18 Charts from the Royal Observatory, Greenwich ; 64 Charts from the Paris Observatory, and 10 Charts from the Observatory, San Fernando.

The Value of the Constant of Refraction. By Dr. L. de Ball.

(*Communicated by the Astronomer Royal.*)

Professor Bauschinger, in his researches on astronomical refraction,* gives the following values for the constants of refraction as reduced to the height of the barometer of 760 mm. and to the temperature of 0° C. of the internal and the external thermometer, to which I add that lately determined by Dr. Courvoisier : †

60″·120 Greenwich 1857–65	60″·209 Pulkowa 1865
·192 „ 1877–86	·058 „ 1885
·268 Tab. Pulk.	·104 Bauschinger
·122 Fuss (Pulkowa)	·161 Courvoisier

* *Annals of the Munich Observatory*, vol. iii.

† *Publications of the Heidelberg Observatory*, vol. iii.

At Greenwich and Pulkowa, however, only the reduction of the barometer to 0° C. has been applied, whereas Professor Bauschinger and Dr. Courvoisier have also taken into account the correction for gravitation and the hygrometric state of the atmosphere. A reduction has, therefore, to be applied to the above values deduced from the observations of Greenwich and Pulkowa before they can be compared with the values determined at Munich and Heidelberg. The determination of the values used for these reductions is the purpose of this paper.

For zenith distances less than 84° we can compute the refraction by means of the series

$$(1)\quad \text{Refraction} = \frac{a}{\sin 1''}\,(a_0 \tan z - a_1 \tan^3 \phi\, z + \ldots)$$

where a depends on the density of the air at the place of observation, and the coefficients a_0, a_1, . . . are functions of the temperature and of a. The density of the air at the place of observation can be found when we know the height of the barometer (B), the readings of the internal (τ) and external (t) thermometer, and the vapour pressure (π). In the following pages B and π are supposed to be expressed in millimeters and the temperature in centigrades. When the vapour pressure for each time of observation is not known, but only its mean value π_0, we find for the density of the air ρ (*Monthly Notices*, 1905 June)

$$(2)\quad \rho = \frac{B}{760}\,\frac{1-0{\cdot}000162\tau}{1+0{\cdot}003663t}\,(1-0{\cdot}0000001196h-0{\cdot}00265\cos 2\phi)\left(1-\tfrac{3}{8}\,\frac{\pi_0}{B}\right),$$

where h = the height of the place of observation above the sea level (in meters) and ϕ = the geographical latitude of the place of observation.

In order to compute the value of a, which corresponds to a given ρ, we need only know the value a_0 (the so called constant of refraction), which holds for a definite but arbitrarily chosen density ρ_0. If, namely, c is an absolute constant, then a and a_0 are determined by the equations

$$(3)\quad a = \frac{c\rho}{1+2c\rho}, \qquad a_0 = \frac{c\rho_0}{1+2c\rho_0}$$

whence

$$(4)\quad a = \frac{\rho}{\rho_0}\,\frac{a_0}{1-2a_0\left(1-\dfrac{\rho}{\rho_0}\right)}$$

When ρ_0 = the density of the air at the place of observation for B = 760 mm., $\tau = t = 0°$ C. and vapour pressure = π_0, we have according to (2)

$$(5)\quad \rho_0 = (1-0{\cdot}0000001196h-0{\cdot}00265\cos 2\phi)\left(1-\tfrac{3}{8}\,\frac{\pi_0}{760}\right)$$

From (2) and (5) it follows that

$$(6)\quad \frac{\rho}{\rho_0} = \frac{B(1-0{\cdot}000162\tau)}{760(1+0{\cdot}003663t)}$$

If in equation (4) we substitute this expression and the supposed known value of a_0 which corresponds to the density ρ_0 given in (5), we obtain a ; by means of a and t the refraction is directly deduced from the equation (1). If, therefore, the constant of refraction corresponds to the density given in (5), we have to apply to the observed height of the barometer the reduction to 0° C. only. Reversely : *when to the observed height of the barometer we apply only the reduction to* 0° *C.* (Greenwich, Pulkowa), *and we derive from the observations the correction of an approximate value adopted for* a_0, *the new value of the constant of refraction will hold for the density of the air given in* (5).

If besides the height of the barometer and the temperature we also know the observed vapour pressure π, we obtain instead of the approximate value (2) of ρ its exact value when we substitute π for π_0 ; therefore we have

$$(7)\quad \rho = \frac{B}{760}\,\frac{1-0{\cdot}000162\tau}{1+0{\cdot}003663t}\,(1-0{\cdot}0000001196h - 0{\cdot}00265\cos 2\phi)\left(1-\tfrac{3}{8}\frac{\pi}{B}\right)$$

Choosing for ρ_0 the density of the air at the sea level and at the geographical latitude of 45° for B = 760 mm., $\tau = t = 0$°C., $\pi = 6$ mm., we obtain

$$(8)\quad \rho_0 = 1-\tfrac{3}{8}\,\tfrac{6}{760}$$

and from (7) and (8) when, for brevity, we put

$$(9)\quad B\{1-0{\cdot}000162\tau-0{\cdot}0000001196h-0{\cdot}00265\cos 2\phi + \tfrac{3}{8}\left(\tfrac{6}{760}-\frac{\pi}{B}\right)\} = b,$$

it follows that

$$(10)\quad \frac{\rho}{\rho_0} = \frac{b}{760(1+0{\cdot}003663t)}$$

Here we may repeat—*mutatis mutandis*—the remarks made above in connection with the equation (6), and it appears that: *If instead of the observed height of the barometer B we use the barometer height b, as reduced according to the equation* (9) [Bauschinger, Courvoisier], *the value of the constant of refraction deduced from the observations holds for the density of the air given in* (8).

In order to reduce the values of the constants of refraction, determined in Greenwich and in Pulkowa, to that density of the air for which the values of Professor Bauschinger and Dr. Courvoisier hold we must put in the equation (4), instead of ρ, the

value given in (8), and, instead of ρ_o, that given in (5). We then obtain

$$(11)\quad a-a_o = a_o\left(0{\cdot}00000196h + 0{\cdot}00265\cos 2\phi + \tfrac{3}{8}\frac{\pi_o-6}{760}\right)$$

We have for

Greenwich	$a_o = 60''{\cdot}156$ (mean),	$h = 47^m$,	$2\phi = 102^\circ\ 57'$
Pulkowa	$\,,, = 60''{\cdot}164$,,	,, $= 75^m$,	,, $= 119^\circ\ 33'$

Hence, if first we neglect the member depending on π_o,

Greenwich	$a-a_o = -0''{\cdot}035$
Pulkowa	,, $= -0''{\cdot}078$

Therefore we obtain for *the value of the constant of refraction reduced to the density* $\rho_o = 1-\frac{3}{8}\frac{6}{760}$, *and hence to* $h = 0$, $\phi = 45°$, B = 760 mm., $\tau = t = 0°$ C., $\pi = 6$ mm.

Greenwich	$60''{\cdot}121 + 0''{\cdot}030(\pi_o-6)$
Pulkowa	$60''{\cdot}086 + 0''{\cdot}030(\pi_o-6)$
Munich	$60''{\cdot}104$
Heidelberg	$60''{\cdot}161$

If the observations were equally distributed over the whole year we might accept for π_o the mean from the monthly means of the vapour pressure of Greenwich and Pulkowa respectively, but this assumption on the distribution of the observations is not permissible. However, even if π_o were known, the correction depending on π_o would be uncertain, for it is possible that in the expression for the correction mentioned $\frac{1}{8}$ has to be put in the place of $\frac{3}{8}$ (*Monthly Notices*, 1905 June).

Vienna-Ottakring : 1905 *November* 13.

Note on an Experiment on Lateral Refraction.

By B. F. E. Keeling, Survey Department, Egypt.

(*Communicated by Professor H. H. Turner.*)

A geodetic triangulation is about to be made by the Egyptian Survey Department with the object of linking up the South African survey along the 30° E. meridian and the Russian triangulation. The first question which was raised was the position of the chain, whether to utilise in the main the Nile Valley or to take the chain wholly to east or west of it. From the point of view of convenience and economy the former is evidently to be preferred, but it was asked whether it would not

militate against accuracy to have a large number of sights with their end sections over the desert and the middle sections over the cultivated Nile Valley. It was feared that there might be considerable differences in the apparent lines of sight between day and night, and it was with the object of testing the stability of the apparent line joining two stations that this experiment was undertaken.

The experiment was on the lines of that by C. M. v. Bauernfeind,* but instead of four only two signals were observed. The theodolite used was a 40-centimetre one made by Brünner in (about) 1860, and readjusted recently by Cooke & Sons. It has an object-glass 60 mm. in diameter and of about 750 mm. focal length. The eyepiece micrometer reads directly to seconds. The theodolite was mounted on a brick pier isolated from the floor in one of the buildings of Helwan Observatory, about 100 metres above the Nile. The first signal was about 600 metres distant, and consisted of a metal plate mounted in a brick wall. In the plate was a hole one centimetre in diameter which was illuminated from behind by a heliograph during the day and a bicycle lamp at night. Between the theodolite and this mark was a small ravine 10 to 30 metres deep. The distant station was situated on the other side of the Nile Valley on a low hill near the pyramids of Giza, and was also some 100 metres above the Nile. It was about 25 kilometres from the theodolite.

A 5-in. heliograph was used by day and a powerful motor lamp at night, both being self-centring on a brass support cemented into a brick pillar.

The line of sight crossed about 7 kilometres of desert at each end with 11 kilometres of cultivation in the middle. The two signals were nearly in the same straight line as seen from the theodolite, the angle between them being about 10′. The measures were made entirely with the eyepiece micrometer, the two signals being successively brought into the field of view by the slow motion of the vertical circle.

Two series of observations were made. The first was spread over five days in April 1905. The work was a good deal interrupted by a sand storm which was blowing for a great part of the time. The maximum and minimum temperatures are given for each day, and it will be seen that the range was large and the temperatures high.

The second series was made in December 1905. The weather was for the most part clear, with mists which interrupted the observations in the early morning. Both the temperatures and the daily range were very much lower than in the former experiment, whilst the humidity was higher. The effective width of cultivation was greater, as the flood-water had only just been drawn off the land, and the whole of the 11 kilometres was wet.

* *Ergebnisse aus Beobachtungen der terrestrischen Refraktion.* München, Akad. Abhandl., xiii., 1880.

The tables which follow give the results of the observations. No accurate determination of the value of the micrometer was made in either case, so the two series are not comparable with each other as regards absolute values.

The calculated error of a single observation considered by itself was from $\pm 0{\cdot}1$ to $\pm 0{\cdot}3$ of a division.

It does not appear that there is any regular diurnal swing of the line of sight, and indeed the divergence of any observation from the mean is so little greater than the calculated probable error of the observation that the experiments, so far as they go, show that if observations are spread over a few days the Nile Valley will not be unfavourable to triangulation. The line of sight was intentionally lower than will usually be the case in the actual triangulation.

Incidentally some information can be gleaned as to the hours of work available, though of course the number of days over which the work extended was small. The light from the heliograph was always in vibration; its apparent diameter was often as much as 60 in., and often numerous sparks were shot off in all directions. But still the observations seem to show that it is only rarely that work need be discontinued, and, moreover, that the morning observations and condition of the atmosphere were not greatly inferior to those in the evening.

TABLE I.

Date.	Time.	Observed Angle 3t+divs.	Mean—Observed E.	Temp. ° C.	Relative Humidity. %	—	Temp. Max. ° C.	Temp. Min. ° C.	Humidity %. 8 am.
18 4 05	7 p.m.	19·6	−0·4	30	4		...	...	...
	9 p.m.	19·5	−0 5	26	10	Helwan	37	14	49
	11 p.m.	20·2	+0·2	25	8	Giza *	36	11	60
19 4 05	6 a.m.	20·6	+0·6	20	16				
	7 a.m.	20·8	+0·8	25	14				
	7 p.m.	20·5	+0·5	36	4	Helwan	39	18	21
	9 p.m.	20·5	+0·5	26	31	Giza *	39	14	53
20 4 05	1 a.m.	19·4	−0·6	20	40				
	7 a.m.	21·0	+1·0	24	13				
	9 a.m.	19·4	−0·6	27	33	Helwan	41	16	35
	11 a.m.	20·4	+0·4	35	9	Giza *	36	15	65
21 4 05	7 p.m.	19·5	−0·5	37	11				
	9 p.m.	19·5	−0·5	33	10	Helwan	42	21	24
	11 p.m.	19·2	−0·8	33	7	Giza *	41	14	56
22 4 05	3 a.m.	19·7	−0 3	29	8				
	5 a.m.	19·9	−0·1	27	11				
	7 a.m.	20·4	+0·4	27	14	Helwan	42	26	6
	9 a.m.	20·3	+0·3	34	7	Giza *	41	24	21
	7 p.m.	20·5	+0·5	37	7				
	9 p.m.	19·6	−0·4	20	15				
	Mean	20·02							

1 div. = 1 sec. nearly.

* Meteorological station in the cultivation.

TABLE II.

Date.	Time.	Observed Angle 3t+divs.	Mean− Observed Divs.	Temp. °° C.	Relative Humidity. — %		Temp. Max. ° C.	Temp. Min. ° C.	Humidity % 8 a.m.
4 12 05	10 a.m.	19·7	−0·7	18	38				
	2 p.m.	20·9	+0·5	21	35				
	6 p.m.	20·0	−0·4	17	38	Helwan	22	10	63
	8 p.m.	20·0	−0·4	15	54	Giza	24	8	79
	Midn.	19·9	−0·5	12	46				
5 12 05	2 a.m.	20·2	−0·2	12	51				
	10 a.m.	20·4	±0·0	16	46				
	Noon	20·7	+0·3	20	36				
	2 p.m.	20·8	+0·4	21	32	Helwan	22	10	51
	4 p.m.	20·4	±0·0	21	25	Giza	25	8	66
	6 p.m.	21·0	+0·6	18	43				
	8 p.m.	20·9	+0·5	16	46				
6 12 05	8 a.m.	20·6	+0·2	12	59				
	10 a.m.	20·5	+0·1	17	50				
	Noon	21·6	+1·2	19	42				
	2 p.m.	20·8	+0·4	22	36	Helwan	22	9	58
	4 p.m.	20·4	±0·0	21	42	Giza	23	9	69
	6 p.m.	19·5	−0·9	19	54				
	10 p.m.	20·6	+0·2	16	68				
7 12 05	10 a.m.	21·1	+0·7	20	59				
	Noon	20·6	+0·2	22	42				
	2 p.m.	20·6	+0·2	23	39				
	4 p.m.	19·4	−1·0	22	43	Helwan	24	14	76
	6 p.m.	20·6	+0·2	20	48	Giza	26	9	100
	8 p.m.	20·8	+0·4	18	59				
	Midn.	20·7	+0·3	17	72				
8 12 05	10 a.m.	19·8	−0·6	20	61				
	Noon	20·1	−0·3	23	43				
	2 p.m.	19·8	−0·6	23	40	Helwan	23	14	74
	4 p.m.	20·5	+0·1	22	50	Giza	24	11	88
	8 p.m.	20·6	+0·2	18	72				
	Mean	20·4							

1 div. = 1 sec. nearly.

I have to tender my best thanks to Captain H. G. Lyons, R.E., Director-General of the Survey Department, for providing facilities for this work and sanctioning its publication.

Note on the Motion about an Attracting Centre of slowly increasing Mass. By H. C. Plummer, M.A.

1. The dynamical problem of motion under the attraction of a body of increasing mass was suggested by Oppolzer * in an attempt to explain a part of the secular acceleration of the Moon as a result of the deposition of meteoric matter on the Earth. It has since been discussed by Gyldén,† Mestschersky,‡ Lehmann-Filhés,§ and E. Strömgren.‖

The same theory is recalled by Mr. Cowell's conclusion that the motion of the Earth round the Sun is also affected by a secular acceleration. It is true that the idea that this can be attributed to a gradual increase in the mass of the Sun is not borne out by Mr. Cowell's result for the motion of *Mercury*; but this consideration may not be quite decisive, since the motion of this planet is known to be incompletely explained by theory. However this may be, the effect of an increase in the central body is a point of some interest, and a short discussion is here given of the simplest case, that in which the rate of increase is constant.

2. Let $\mu u^2(1+at)$ represent the law of central attraction, u being the reciprocal of the radius vector. Since the force is central, the integral of areas holds, and the equations of motion may be written

$$r^2\frac{d\theta}{dt} = h \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$\frac{d^2u}{d\theta^2}+u = \frac{\mu}{h^2}(1+at) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Now if powers of a above the first be neglected, it is easily verified that these equations are satisfied by the solution

$$u = \frac{\mu}{h^2}\{1+e\cos(\theta-\gamma)\}(1+at) \quad \ldots \quad \ldots \quad (3)$$

where

$$u = \frac{\mu}{h^2}\{1+e\cos(\theta-\gamma)\} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

can be regarded as the undisturbed (though not the osculating) orbit at the time $t = 0$. Let R and T be the radius vector and time in this undisturbed orbit corresponding to the anomaly θ. Then in the disturbed orbit

$$r = \mathrm{R}/(1+at)$$

and

$$\int \mathrm{R}^2 d\theta = h\int(1+at)^2\,dt$$

or

$$\mathrm{T} = t(1+at)$$

* *A. N.*, 2573. † *A. N.*, 2593. ‡ *A. N.*, 3153, 3807.
§ *A. N.*, 3480. ‖ *A. N.*, 3897.

Hence at any time the deviations of the disturbed from the undisturbed orbit for the same anomaly θ are given by

$$\frac{\Delta r}{r} = \frac{\Delta t}{t} = -at \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

and the increase in the anomaly in a given time t is

$$-\frac{d\theta}{dt}\Delta t = ahr^{-2}t^2 \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

3. The required results are thus obtained more simply and directly than by the variation of elements; but the first-order variations of e, γ and a can be deduced very easily. In the equation (3) of the actual trajectory, t is to be regarded as a function of θ; the osculating orbit at the point θ is

$$u = \frac{\mu}{h^2}\{1 + e' \cos(\theta - \gamma')\}(1 + at) \quad \ldots \quad \ldots \quad (7)$$

where t is to be regarded as constant. The identity of the radius and tangent in the two curves gives

$$e' \cos(\theta - \gamma') = e \cos(\theta - \gamma)$$
$$e' \sin(\theta - \gamma') = e \sin(\theta - \gamma) - ahr/\mu$$

which lead to

$$\Delta(e \cos\gamma) = -ahr \sin\theta/\mu$$
$$\Delta(e \sin\gamma) = \quad ahr \cos\theta/\mu$$

or finally to

$$\Delta e = -\frac{ah}{\mu} r \sin(\theta - \gamma) = -a \cdot \frac{h^3}{\mu^2} \cdot \frac{\sin E}{(1-e^2)^{\frac{1}{2}}} \quad \ldots \quad (8)$$

$$\Delta\gamma = \quad \frac{ah}{e\mu} r \cos(\theta - \gamma) = \quad a \cdot \frac{h^3}{\mu^2} \cdot \frac{\cos E - e}{e(1-e^2)} \quad \ldots \quad (9)$$

where E is the eccentric anomaly corresponding to θ.

The mean distance in the osculating orbit is

$$a' = \frac{h^2}{\mu(1-e'^2)(1+at)}$$

Hence

$$\Delta a = a\left(-at + \frac{2e\Delta e}{1-e^2}\right)$$
$$= -aa\left\{t + \frac{2h^3}{\mu^2} \cdot \frac{e \sin E}{(1-e^2)^{\frac{3}{2}}}\right\} \quad \ldots \quad \ldots \quad (10)$$

Equations (8), (9) and (10) may be compared with equations (25) of Dr. Strömgren's paper; the two sets differ by additive constants which can be introduced into the above to annul the variations at a given epoch, as $t = 0$. The variations found above are referred to the intermediate orbit whose equation is (4).

University Observatory, Oxford:
1906 *January* 10.

Mean Areas and Heliographic Latitudes of Sun-spots in the Year 1904, *deduced from Photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn; at Kodaikánal Observatory, India; and in Mauritius.*

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lxv. p. 151, and are deduced from the measurements of photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn; at the Kodaikánal Observatory, India; and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily area of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1904; and Table II. gives the same particulars for the entire year 1904 and the three preceding years for the sake of comparison. The areas are given in two forms: first, projected areas; that is to say, as seen and measured on the photographs, these being expressed as millionths of the Sun's apparent disc; and next areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1904 the mean daily area of the whole spots (corrected for foreshortening) and the mean heliographic latitude of the spotted area for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results for the three preceding years being added, as in the case of Table II.

Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*, and for the years 1889 to 1902 on pp. 465 and 466 of vol. lxiii., and for the years 1901 to 1903 on pp. 152 and 153 of vol. lxv.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon of 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

The principal features of the record for 1904 are:

1. The comparatively slow, though steady, increase in the mean daily spotted area, the umbræ showing an advance on 1903 of only 32 per cent.; the whole spots of 44 per cent. The years in the two preceding cycles showing this relation to the years which they followed were 1882 and 1893, when the actual maximum was very close at hand.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
	1903. d							
672	Dec. 20·64	26	57	353	1164	46	287	1338
	1904.							
673	Jan. 16·98	27	93	638	883	65	456	1000
674	Feb. 13·32	26	61	401	899	45	296	1015
675	Mar. 11·65	27	75	483	1413	52	347	1532
676	Apr. 7·94	28	209	1398	1547	143	1018	1658
677	May 5·20	26	42	298	1914	30	217	2059
678	June 1·41	28	61	495	1580	41	339	1628
679	28·61	27	91	715	1928	65	525	1966
680	July 25·82	27	67	516	2005	48	385	2100
681	Aug. 22·05	27	71	608	1697	50	454	1805
682	Sept. 18·30	28	101	713	1858	72	520	1933
683	Oct. 15·59	27	93	633	1719	73	506	1888
684	Nov. 11·89	27	103	638	1714	89	592	1969
685	Dec. 9·20	26	149	1054	2600	106	750	2813

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1901	359	14	41	23	86	29	29
1902	349	14	86	163	10	62	178
1903	350	67	434	870	51	339	969
1904	363	93	653	1639	67	488	1761

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots north of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Spots south of the Equator. Mean of Daily Areas.	Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	1903. d			°		°	°	°
672	Dec. 20·64	26	163	18·70	124	16·59	+ 3·40	17·78
	1904.							
673	Jan. 16·98	27	312	16·82	144	14·70	+ 6·87	16·20
674	Feb. 13·32	26	68	15·73	229	13·82	− 7·08	14·25
675	Mar. 11·65	27	276	13·63	72	17·39	+ 7·23	14·40
676	Apr. 7·94	28	302	14·58	717	14·49	− 5·88	14·52
677	May 5·20	26	72	17·13	145	20·09	− 7·78	19·11
678	June 1·41	28	267	16·03	72	18·82	+ 8·62	16·63
679	June 28·61	27	254	15·05	272	18·97	− 2·52	17·05
680	July 25·82	27	200	15·45	185	16·49	+ 0·10	15·95
681	Aug. 22·05	27	54	18·77	400	17·62	−13·28	17·76
682	Sept. 18·30	28	271	18·95	249	19·81	+ 0·39	19·36
683	Oct. 15·59	27	300	12·26	206	18·34	− 0·15	14·73
684	Nov. 11·89	27	477	19·06	115	19·98	+11·50	19·24
685	Dec. 9·20	26	629	17·04	121	16·44	+11·65	16·95

Table IV.

Year.	No. of Days on which Photographs were taken.	Spots north of the Equator. Mean of Daily Areas.	Spots north of the Equator. Mean Heliographic Latitude.	Spots south of the Equator. Mean of Daily Areas.	Spots south of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1901	359	22	8°·59	6·6	16°·27	+2°·82	10°·37
1902	349	42	18·81	21	15·29	+7·48	17·64
1903	350	133	18·12	206	21·10	−5·75	19·93
1904	363	268	16·33	220	16·88	+1·37	16·57

2. Not only has the general increase of activity in 1904 been slight, but no single rotation of the year has equalled either the 11th or 12th rotations of 1903 in spotted area, and only one—that beginning 1904 April 7, No. 676—has approached them. For the rest of the year the spot activity has been fairly evenly distributed, with a tendency to increase as the year went on.

3. The faculæ have shown a much more marked increase than the spots, the advance on 1903 being 82 per cent. The progress has gone on steadily throughout the year, the last rotation showing much the greatest area for the faculæ.

4. Comparing the whole spots of the two hemispheres, the area for the northern has been to that of the southern as 55 to 45. This is a return to the precedent of the two preceding cycles, in so far that the northern hemisphere showed a superiority over the southern during the years of chief increase of the solar activity in those two cycles; but is a departure from their precedent in that the balance had swung over to the southern side by the time that the amount of increase had become as small as 44 per cent. The near approach to equality between the two hemispheres would mean, according to the precedent of the last two cycles, that the maximum had not yet been reached, but might be expected in 1905 or early in 1906.

5. Neither hemisphere has been undisturbed for a complete rotation at any time during 1904.

6. Nor was there a single day without spots in the year. This is in sharp contrast to 56 such days in 1903, 248 in 1902, and 289 in 1901.

7. The distribution of spots in latitude in each hemisphere, equally with their distribution between the two hemispheres, appears to point to the near approach of the maximum. The chief spot activity has lain between 24° and 10° in both hemispheres, but has not been restricted to it, for there has been occasional action over the entire zones 33° to 6°, and one or two instances of sporadic spots outside even these wide limits have been noticed. Thus on 1904 November 28 a spot was seen in N. lat. 41°, and on November 29 another in N. lat. 38°; whilst an equatorial group was observed on 1904 January 1. The

appearance of spots over so wide a range of latitude is usually an indication that the maximum is close at hand.

8. The comparison of the mean distance from the equator of all spots for 1904 with the corresponding years of the two preceding cycles is interesting, and marks the present cycle as decidedly unlike the two preceding cycles in its progress. The centre of gravity of the spot-zone has already approached considerably nearer to the equator than in the year before maximum of those two cycles, but the area attained is much smaller. The area in fact is that of nearly three years before maximum, but the mean distance from the equator approaches that of the year of maximum, as the following little table will show :

TABLE V.

Cycle.	Date of Maximum.	Year.	Mean Distance from Equator of all Spots.	Mean Daily Area of Whole Spots.
			°	
1879–1889	1883·9	1880	19·80	416
		1881	18 21	730
		1882	17·81	1002
		1883	13·04	1155
1890–1901	1893·9	1890	21·99	99
		1891	20·31	569
		1892	18·39	1214
		1893	14·49	1464
1902– ...	...	1904	16·57	488

9. The number of separate groups of spots was 84 per cent. greater than in 1903, so that the average size of the groups was not quite as great as in the earlier year. There was no single group at all comparable in area with the great group of 1903 October 4–17. In all, the groups of 1904 were 276 in number, 165 being in the northern hemisphere and 111 in the southern.

Royal Observatory, Greenwich:
1906 *January* 8.

Observation of Comet b 1904 (*Encke*) *from a Photograph taken with the* 30*-inch Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

Date and G.M.T. 1904 d h m s	Apparent R.A. h m s	Apparent Dec. ° ′ ″	Log. Δ.	Corr. for Parallax R.A. s	Corr. for Parallax Dec. ″
Dec. 7 6 42 19	20 50 20·95	+5 51 24·6	9·6830	+·53	+13·3

Royal Observatory, Greenwich:
1906 *January* 5.

Observations of Comet b 1905 *from Photographs taken with the 30-inch Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The following positions of Comet *b* 1905 were obtained from photographs taken with the 30-inch reflector. As a rule these were four images on each plate with exposures of from 1^m to 2^m. The plates were measured in the astrographic micrometer. Four reference stars were taken in each case, situated as symmetrically as possible about the comet. The positions of the reference stars were derived from the Catalogues of the Astronomische Gesellschaft.

Date and G.M.T. 1905				Apparent R.A.			Apparent Dec.			Log. Δ.	Corr. for	Parallax
d	h	m	s	h	m	s	°	′	″		R.A. s	Dec. ″
Nov. 20	10	9	41	23	54	39·31	62	8	28·7	9·3825	+1·77	−3·6
21	8	13	25	23	47	2·78	54	1	25·5	9·3912	+·30	−1·6
23	9	55	53	23	38	18·44	37	31	24·9	9·4346	+1·01	+10·1
24	6	38	12	23	36	18·09	31	43	40·3	9·4649	−·29	+10·3
27	6	13	18	23	32	21·40	16	35	6·6	9·5657	−·25	+13·7
29	6	27	34	23	31	6·11	9	43	1·8	9·6312	−·12	+10·8

Further details of the observations will be given in the Greenwich volume.

Royal Observatory, Greenwich:
1906 *January* 5.

Observations of Mösting A made with the Altazimuth and Transit Circle at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

From the beginning of 1905, in concert with the Cape Observatory, observations of Mösting A have been made on the meridian when the Moon was in the second or third quarter. The primary object is a determination of the parallax of the Moon from the observations of N.P.D., the culminators being also observed at both observations for the elimination of the instrumental errors.

At Greenwich the limbs have as far as possible been observed as well as the crater, as in this way the observations of 1L are connected with those of 2L, and those of NL with SL.

The following table gives the tabular errors of the Moon's

centre in right ascension from the Greenwich meridian observations with the altazimuth and transit circle. Those in N.P.D. cannot be given at present, as the corrections for R—D discordance for the two instruments have not yet been determined. The observations in N.P.D. of the limbs and crater with the same instrument can, however, be compared, as they are equally affected by the R—D corrections.

Apparent Error of the Tabular Right Ascensions of the Moon's Centre, from Observations of Mösting A and of the Moon's Limbs.

Date.	Mösting A		Limb.		Limb
	Altaz.	T.C.	Altaz.	T.C.	Obsd.
	s		s	s	
Jan. 14	−0·33	...	−0·37	−0·33	1
25	− ·09	...	− ·17	− ·08	2
27	− ·18	...	− ·25	− ·13	2
Feb. 17	− ·62	...	− ·60	− ·58	1
20	− ·32	...	...	− ·29	2
Mar. 14	− ·41	...	− ·52	− ·50	1
15	− ·66	...	− ·62	− ·67	1
17	− ·74	...	− ·74	− ·63	1
18	− ·70	− ·72	− ·67	− ·74	1
19	− ·62	− ·59	− ·52	− ·54	1
21	− ·56	− ·64	− ·40	− ·43	2
22	− ·36	...	− ·20	− ·27	2
25	− ·27	...	− ·20	+ ·02	2
Apr. 14	− ·73	...	− ·68	− ·75	1
18	− ·58	...	− ·54	− ·55	1
22	− ·37	− ·16	− ·34	− ·17	2
23	− ·26	...	− ·20	− ·23	2
May 15	− ·58	...	− ·57	− ·57	1
17	− ·51	− ·44	− ·47	− ·48	1
21	− ·18	...	− ·19	...	2
22	− ·14	...	− ·31	+ ·01	2
23	− ·16	...	− ·07	− ·11	2
June 14	− ·59	...	− ·40	− ·37	1
18	− ·35	...	− ·31	− ·22	2
June 19	−0·21	...	−0·29	−0·14	2
20	− ·22	...	− ·19	− ·20	2
22	− ·22	...	− ·05	− ·11	2
July 13	...	−0·59	...	− ·43	1
15	...	− ·44	...	− ·41	1
20	...	− ·15	...	− ·08	2
21	− ·31	...	− ·25	− ·04	2
Aug. 11	...	− ·40	...	− ·46	1
16	...	− ·22	...	− ·19	2
Sept. 7	− ·32	− ·16	− ·26	− ·20	1
8	− ·35	− ·22	− ·32	− ·45	1
12	− ·22	− ·07	− ·18	− ·19	1
18	− ·35	...	− ·23	− ·19	2
19	− ·33	− ·19	− ·33	− ·38	2
20	...	− ·39	− ·48	− ·55	2
Oct. 7	− ·32	...	− ·26	− ·28	1
10	− ·19	− ·25	− ·01	− ·23	1
13	...	...	− ·18	− ·21	2
16	− ·37	− ·44	− ·33	− ·29	2
19	− ·45	...	− ·42	− ·45	2
Nov. 6	− ·24	− ·21	− ·24	− ·16	1
7	− ·23	− ·13	− ·20	− ·20	1
Dec. 8	...	− ·38	− ·18	− ·28	1
9	− ·24	− ·33	− ·29	− ·43	1

The most striking features in the above are (1) the close agreement of the observations made with the two instruments and by the two methods of observing ; and (2) the large amount of the Moon's error in right ascension, amounting to nearly $-0^{s}\cdot40$ in the mean for the year. This value is confirmed by the observations of limbs in the first and last quarters with the transit circle and by the extra-meridian observations with the altazimuth.

The following table gives the difference of R.A. or N.P.D. of the centre as determined from observations of the crater or a limb when both were observed with the same instrument. The differences of R.A. can be found from the table given above.

Differences of R.A. of Moon's Centre.				Differences of N.P.D. of Moon's Centre.			
Altazimuth.		Transit Circle.		Altazimuth.		Transit Circle.	
Möst. A. −1L	Möst. A. −2L	Möst. A. −1L	Möst. A. −2L	Möst. A. −NL	Möst. A. −SL	Möst. A. −NL	Möst. A. −SL
s	s	s	s	"	"	"	"
−·04	−·08	−·02	+·21	+0·94	−0·34	−0·59	−1·94
+·02	−·07	+·05	−·01	+0·31	+0·21	+2·49	−0·67
−·11	+·16	−·04	+·07	−2·72	+0·36	+1·10	+1·89
+·04	+·16	+·16	+·03	+3·24	−3·57	−2·32	+3·37
·00	+·07	+·03	−·19	−0·34	+0·21	−1·33	+0·11
+·03	+·03	−·06	−·16	−2·97	+1·76	+0·11	+1·62
+·10	+·06	−·04	+·15	−0 77	+0·11	+0·34	+2·62
+·05	−·01	−·23	...	−1·61	+0·81	−0·39	+0·53
+·04	−·17	−·12	...	+2·54	+0·66	−1·50	+1·13
+·01	+·09	+·02	...	−0·09	+0·70	+0·22	...
+·04	+·04	+·05	...	−1·14	+0·93	+1·25	...
+·19	−·08	−·07	...	+1·02	−0·43	+0·14	...
+·06	+·03	+·10	...	−0·18	...	...	...
+·03	+·17	+·10	...	−1·60	...	...	...
+·04	+·06	...	...	...	...	...	...
+·06	+·12	...	...	...	...	...	...
+·18	·00	...	...	...	...	...	...
·00	+·04	...	...	...	...	...	...
+·03	+·03	...	...	...	...	...	...
−·05	...	...	...	...	...	...	...
Mean +·036	+·033	−·019	·014	−0·24	−0·02	− 0·04	+0·96

The differences of right ascension of Mösting A given by the two instruments are as follows :—

Altazimuth − Transit Circ'e.

s	s	s
−·02	+·16	−·07
+·03	+·13	+·03
−·08	+·14	+·10
+·21	+·14	−·09
+·07	−·06	
Mean	+s·05	

The observations are not sufficient for much weight to be attached to these results, but it seems desirable to draw atten-

tion to them in view of the questions attaching to the observations of limbs.

As showing the amount of accidental error in observations of the Moon, the following comparison of altazimuth observations of Mösting A with transit-circle observations of the limbs has been made in R.A. As these are essentially different observations with different instruments, this comparison will give reliable values of the accidental errors.

Excess of Right Ascension of the Moon's Centre as obtained from Altazimuth Observations of Mösting A over Transit Circle Observations of the Moon's Limbs.

s	s	s	s
·00	+·13	+·05	+·16
+·01	+·09	+·22	−·05
+·05	+·29	+·13	+·04
+·04	−·02	+·07	−·04
+·03	+·03	+·02	+·08
−·09	+·20	+·11	·00
−·01	+·03	+·27	+·08
+·11	+·01	+·12	+·03
−·04	+·03	−·10	−·19
+·08	+·15	+·03	...

The algebraic mean of these quantities is $+^{s}\cdot055$, and the arithmetic mean $\pm^{s}\cdot083$ or $\pm^{s}\cdot072$ when the mean $+^{s}\cdot055$ is taken out. If the observations of Mösting A with the altazimuth and of the limb with the transit circle be taken as equally accurate, the probable error of an observation is $\pm^{s}\cdot052$, or $\pm^{s}\cdot044$, according as the uncorrected or corrected value of the arithmetic mean is taken.

Royal Observatory, Greenwich:
1906 *January* 11.

Lunar Nomenclature. By Walter Goodacre.

I think it will be readily granted by those who take an interest in lunar topography that the publication of Mr. S. A. Saunder's catalogue of 1433 measured points on the Moon's surface marks an epoch in selenography.

The completion of a task of this magnitude and importance could not fail to bring up once more the question of lunar nomenclature. The chaotic condition of this subject which at present exists and the urgent need for reform have been fully illustrated and set forth in the paper read by Mr. Saunder at the last meeting of the Society.

It now remains to be seen if it is not possible that some method can be devised by which the matter may be placed on some final and comprehensive basis.

Without going over the ground already covered by Mr. Saunder, it is sufficient to say that the nomenclature of Riccioli in the main was adopted by Beer and Mädler, and it has become the standard recognised by all subsequent selenographers, though all have made additions or alterations to it as they thought fit.

The real difficulty in lunar nomenclature is found to arise when we seek to formulate a system for marking and cataloguing the minor details which abound on the Moon's surface.

One great step towards the solution of this difficulty could be taken by dividing the Moon's surface into districts or provinces analogous to English counties, each of which would be associated as far as possible with some well-marked object already named as a centre.

This plan was proposed to the late W. R. Birt, F.R.A.S., by the late Rev. Dr. Richards, and was published in the *E.M.*, 1878 April 19. Mr. Birt expressed his approval of the scheme, and it was adopted, I believe, to some extent by the Council of the Selenographical Society. Had the plan been put to the test practical difficulties almost insurmountable would have been encountered, arising principally from the fact that whilst lunar charts, such as those of Neison and Schmidt, were then in existence, and could easily have been divided into conveniently sized districts, the boundary lines must of necessity have been of a purely arbitrary nature and liable to constant alteration, because in practice they would have been found in most cases out of harmony with the natural boundaries, as revealed in the telescope.

The numerous and excellent lunar photographs now in existence, and in which the true configuration of the surface in every part can be seen under suitable angles of illumination, will afford a ready means of tracing natural boundaries between the various objects, and thus rendering the task, which was impossible before, easy of accomplishment.

Having got our boundaries thus fixed, the question now arises as to the manner in which we are to mark and catalogue the various objects within these limited spaces, and it is upon this point that so many opinions are likely to arise, and from the discussion of which it may be hoped a generally accepted system may result.

It is purely with the object of eliciting the views of others that I venture to explain my own on this matter.

The publication of Mr. Saunder's catalogue, already referred to, makes some settlement of this question one of urgency.

In support of this statement I may mention one fact which, I think, amply bears it out.

In glancing down the columns in this catalogue it will be

seen that a number of objects whose positions he has measured are entered without a name or even a letter or number, showing that they are not marked in any way (if shown) on the various maps he has consulted. (A hurried count of these anonymous objects makes their number to be no less than 841 out of 1433.) In many cases there is no agreement between the maps in the lettering of minor objects, which renders it impossible to draw up a correct catalogue.

The want of a suitable method of lunar nomenclature was recognised by the Lunar Committee appointed more than thirty years ago by the British Association, when Mr. Birt and his colleagues drew up an entirely new system, which was as follows :

The Moon's surface was divided into the usual four quadrants —N.W., N.E., S.E., and S.W.—and numbered I. to IV., using Roman figures.

Each of these quadrants was again divided into sixteen grand divisions, distinguished by capital letters from A to Q, and consisting of an area of 25° square, except towards the limb, where of necessity only 15° remain on this hemisphere, and the remaining 10° extend into the further side, which is brought into view by libration.

Each of these grand divisions of 25° was further subdivided into twenty-five areas of 5° square, lettered in the same manner as the grand divisions with Greek letters, α to ω, the last space being left blank.

Finally, any object is distinguished by a number attached to the symbol denoting the small area of 5° square, which it is in, and also the quadrant. Thus I.A. α 50 would indicate that the small object numbered 50 was in the small 5° area marked α, which is found in the grand division A in the N.W. or No. 1 quadrant.

This method was comprehensive and complete, but the necessity of using four symbols to indicate an object proves very cumbersome and has not met with general adoption ; besides which the boundary lines would in many cases intersect each other on the site of large formations, so that we might have an object like Plato cut up in such a way as to be more or less in three or four differently numbered areas.

The plan now suggested is that the Moon should be divided into districts, each district having within its limit some well-known formation to which minor objects would be referred.

The largest craters within this area would be lettered with capital Roman letters A, B, C, &c., and the twenty-six letters of the alphabet should suffice ; but to make this certain it would be necessary to apply such letters only to craters above a certain diameter.

Thus, for instance, the walled plain Clavius would form a suitable district, and the craters on the floor and walls would be

lettered as at present and known as Clavius A, Clavius B, and so on.

Then all the minor objects such as craterlets, ridges, hills, clefts, and spots would be simply numbered, and would be known as Clavius 1, Clavius 2, and so on. Reference to the catalogue would give the nature of the object so numbered. In this system it will be seen that we get rid of the necessity of distinguishing each class of objects by a separate class of symbol, and this by the use of a number only ; and, further, this method would have the advantage of crowding the maps with fewer signs or figures than any other which seeks to differentiate one class of object from another by use of a different symbol.

It may be urged as an objection to this scheme that it presupposes the existence of an accurate map to be divided up.

Such does not exist ; but for practical purposes Schmidt's map should be found sufficiently accurate for this purpose, and I would propose that the divisions be first found on photographs and then transferred to the map. The sections or divisions on the map could then be enlarged to any given scale, and have printed upon them a suitable réseau to be used for plotting accurately the position of objects from the coordinates given in Mr. Saunder's catalogue.

Report on Observations of Jupiter, 1904–5, *made at Trincomali, Ceylon.* By Major P. B. Molesworth.

Part I. Preliminary.

Arrangement of Report.—The present paper is in continuation of the observations for 1903–4, given in the *Monthly Notices*, vol. lxv. No. 7. The nomenclature and arrangement are the same in both cases.

Telescope.—The $12\frac{3}{4}$-inch Calver equatorial was again used ; but for the greater part of the observations no driving clock was available, as the clock had been sent home to Messrs. Ottway of Ealing for a new one to be made. At the end of January the new driving clock (a very fine one) was installed and used till the end of the observations.

Scope of the Observations.—Work was begun in the early mornings on 1904 June 3, and carried on steadily till June 20. At this point I was suddenly laid up with a sharp attack of pleurisy and fever, which necessitated my taking leave home as soon as I was convalescent. No astronomical work was done in England owing to ill-health, but observations were resumed as soon as I returned to Trincomali on 1904 November 26. Regular work was carried on up to 1905 February 13, when a spell of very bad observing weather set in, and very few more visual

observations were obtained. I was then experimenting with photographs of *Jupiter* with very promising results, considering the improvised apparatus and the low altitude of the planet.

The number of nights on which C.M. transits were taken was fifty-seven, distributed as follows each month :—

	No. of Nights.		No. of Nights.
1904 June	12	1905 Jan.	16
Nov.	3	Feb.	11
Dec.	14	March	1

The planet was observed visually for a total period of 100 hours, an average of about $1^h\ 40^m$ per night. One thousand five hundred and seventy-seven C.M. transits were taken in an average of 15·8 per hour. Five sets of measures were made for latitude with the bifilar micrometer in 1905 February and March. Experimental photographs were taken on nine nights in February and March, several negatives being obtained each night ; seven of the plates thus obtained were measured for latitude in an improvised measuring machine, and gave fair results which have been combined with those obtained with the micrometer (see page 104). One or two of the more prominent spots were also measured on the negatives for longitude.

Estimations of the colours and intensities of the belts were made on twenty-seven nights. Satellite phenomena were observed on twenty-seven nights, and careful satellite comparisons made on forty-five nights.

The long gap which broke the continuity of the observations from 1904 June to November has greatly detracted from their value. In a great many cases the identification of the markings was very uncertain, and I have therefore only worked out the rotation periods for those zones which I consider reliable.

The publication of results has again been greatly delayed by pressure of work.

Part II. Disc Observations.

I give a general description of the features noticed in the various zones and belts from south to north.

(*AA*) *S. Polar Region.*—Slightly striated, generally of a faint brownish-yellow tinge, the N. edge being slightly darker than the rest. The general tint is a colder grey than that of the N. Polar Region.

(*A*) *S.S. Zone.*—The dullest of all the zones, unusually dull this year ; generally slightly shaded and barely visible. Very few brighter spots were noticed in it, and those seen were of a very transient nature.

(*B*) *S. Temperate Belt.*—Still rather faint, colourless grey. Owing to uncertainties of identification I have not worked out the periods of the markings in it, but they appear to have practically the same motion as in previous years.

(*C*) *S. Temperate Zone.*—Shows very little change since the last apparition, but its general tone seems to be rather brighter. The mean period deduced from eleven spots this year is $9^h\ 55^m\ 20^s{\cdot}23$, showing a slight retardation compared with last year. Denning's two White Spots (*Observatory*, 1904 September, page 345) were repeatedly observed, and show very regular periods of $9^h\ 55^m\ 20^s{\cdot}08$ and $9^h\ 55^m\ 20^s{\cdot}39$ respectively.

(*D*) *S. Tropical Belt.*—Very distinct, dark, and knotted, but rarely seen double in 1904–5. The general tint is a decided slate-grey with sometimes a cast of blue. I have worked out the rotation periods of the spots in it, but in some cases the identification is rather doubtful. The mean period for most of the belt was $9^h\ 55^m\ 20^s{\cdot}63$, but two fairly well-marked spots in $\lambda° = 60°$ and 72° respectively appeared to have an abnormally slow period of $9^h\ 55^m\ 27^s{\cdot}8$. Possibly my identification is at fault.

The Red Spot.—The appearance of this feature is practically unchanged, and my description in 1903–4 still applies. The bay is now quite shallow and symmetrical, and its breadth possibly decreased slightly during the apparition. The dark curved wisp from the following shoulder to the S. Tropical Belt was almost invariably seen, while that from the preceding shoulder was absent except during the passage of the dark area. The following end of the Red Spot itself is still the darkest, but the ringed appearance of the spot was not noticed. The mean period for the year was $9^h\ 55^m\ 40^s{\cdot}00$.

Great S. Tropical Dark Area.—This is the subject of a separate note in Part IV. It was just coming into conjunction with the Red Spot bay when the observations broke off in June, and covered about 75° of longitude on either side of the bay. When next seen in November it appeared very much as in 1903–4, the total length of the shaded area being about 37°, decreasing to about 35° at the end of the apparition. The mean period of the preceding end was $9^h\ 55^m\ 21^s{\cdot}65$, and that of the following end (after conjunction with the Red Spot) $9^h\ 55^m\ 20^s{\cdot}25$, giving a mean period of $9^h\ 55^m\ 20^s{\cdot}95$. In the best observing conditions the complex structure of the dark area was very apparent, consisting of numerous smoky wisps springing from dark knots on the S. edge of S. Equatorial Belt. The brilliant white spots preceding and following the shaded area in the S. Tropical Zone are evidently related to it, and not due to contrast.

(*EFs*) *Other Spots in S. Tropical Zone and S. Edge of S. Equatorial Belt.*—There appear to be several well-defined dark "wave-crests" in the S. edge of S. Equatorial Belt separated by white bays. The best marked of these in 1904–5 almost all occurred in the 120° of longitude following the Red Spot bay. The influence of the "headlong rush" of the great dark area on these markings is very striking, and is dealt with in detail in the note in Part IV. The general tint of the S. Tropical Zone was a bright milky white, brightest just following the Red Spot

bay and on each side of the dark area. Wisps crossing the S. Tropical Zone were very rare except in the region of the dark area.

(*F*) *S. Equatorial Belt.*—Much the most prominent belt on *Jupiter* in 1904–5 ; broad and very dark, of a rich warm brown tint, which showed up very purple in twilight. The *S.* edge has been dealt with above. It is usually very sharp and clean-cut. The centre of the belt is irregularly rifted, the rift having a decided yellowish tinge in June which was not noticed later. The *N.* edge was more distinct and disturbed than in 1903–4, but it is by no means at a maximum of activity. Owing to the uncertainty of identification, I have not worked out the periods of the spots in this latitude ; but it appears to differ little from that obtained in previous years.

(*GK*) *Equatorial Zone.*—Very white with little or no trace of yellow, the S. edge being, as a rule, considerably brighter and more disturbed than the N. edge, though the latter was brightest in 1903–4. The S. edge was active and contained numerous bright spots, while the N. edge was quiescent and remarkably uniform. The activity of the N. edge appears to depend entirely on the breadth and distinctness of the N. Equatorial Belt.

(*H*) *Equatorial Band.*—Very faint, discontinuous, and difficult to see, but certainly more frequently visible than in 1903–4. The wisps crossing the Equatorial Zone were also darker and more frequent this year, though still very difficult to see, except under the best conditions, and rarely traceable N. of the Equatorial band. I can see no signs of the symmetrical arrangement of these wisps described by some observers.

(*L*) *N. Equatorial Belt.*—Very faint and difficult to see well. It seems very narrow, with diffuse edges, and no darker condensations of any sort, being apparently at an absolute minimum of activity. So far as one can judge of colour in so faint an object, it seemed generally a faint colourless grey, with sometimes a slight blue tinge, but always much colder in tone than the S. Equatorial Belt.

(*M*) *N. Tropical Zone.*—Generally fairly bright, but uniform, with very few brighter spots. The activity of this zone also appears to vary with that of the N. Equatorial Belt.

(*MM*) *N. Tropical Belt.*—Very faint and nebulous, with occasionally a very slight bluish tinge. It is very narrow with indefinite edges.

(*NN*) *N. Temperate Zone.*—This is one of the most variable zones on the planet. It is sometimes very bright, and was once in 1904–5 rated as nearly as brilliant as the S. edge of Equatorial Zone. At other times it is very faint and inconspicuous, and generally rather uniform in tone. When brightest it has a milky-white tinge.

(*N*) *N. Temperate Belt.*—Faint and inconspicuous in June, distinct and considerably darker late in the apparition, when a decided sepia tinge was noticed in it. It formed the S. edge of

a very faint yellowish brown shade, which extended from it to the N. Pole.

(*P*) *N.N. Zone.*—Very dull and nearly always slightly shaded. There are very slightly brighter spots here and there in it, but nothing definite.

(*Q*) *N. Polar Region.*—Generally a very decided yellowish brown with once almost a pinkish tinge. It is very slightly striated, and is darkest along its southern edge.

Relative Brightness of Zones.—This was roughly gauged in the same way as in 1903–4 with the following results :—

(G)	S. Edge of Equatorial Zone	1·26
(E)	S. Tropical Zone	2·63
(K)	N. Edge of Equatorial Zone... ...	3·10
(M)	N. Tropical Zone	3·70
(C)	S. Temperate Zone	4·68
(NN)	N. Temperate Zone	5·06
(P)	N. N. Zone	6·87
(A)	S. S. Zone	7·93

Comparing these results with those obtained in 1903–4, the principal changes are the great falling-off in brightness of (K), the N. edge of the Equatorial Zone, and the increase of brightness in (G) S. edge of Equatorial Zone, and (C) S. Temperate Zone.

Rotation-periods in Different Zones.—Owing to the scantiness of the earlier observations, and the large gap (from June to November) which occurred between the earlier and later observations, the identification of many of the markings has been very difficult. I have therefore only worked out the periods for those zones in which the identification can be relied upon. The observations for the other zones have all been booked on the zone diagrams, and are available if required for comparison with the observations obtained by others.

The zones for which rotation-periods have been calculated are as follows :—

(C) S. Temperate Zone ; (D) S. Tropical Belt ; Red Spot ; Great S. Tropical Dark Area ; (EFs) Other Spots in S. Tropical Zone ; and S. Edge of S. Equatorial Belt.

Even in these zones I may have made mistakes in the identification of some of the spots, except in the case of the Red Spot, and the S. Tropical Dark Area, which are unmistakable. The shortness of the period of observation of the E and Fs spots may have led to error in identification, but I think the deduced period may be taken as fairly reliable.

The mean rotation-periods in different zones are given in Table I.

Measures.—No measures could be taken until very late in the

season owing to the absence of a driving-clock. After the new clock arrived I made five sets of measures with the filar micrometer in February and March. The measures were made in twilight, the planet being then very low and the definition, as a rule, unsatisfactory.

I have also measured the latitudes of the principal belts on seven of the best negatives, taken also in February and March. I used an improvised measuring machine, and the negatives are far from perfect, though they show a good deal of detail. The results are fairly accordant ; and this method, if carried out with proper apparatus, would, I think, give very valuable results in the future.

In reducing the latitudes no allowance has been made for polar compression.

The means of both photographic and visual measures are given in Table II. The results, compared with 1903–4, seem to show an extension of the S. Equatorial Belt southwards, the motion being shared by the S. Tropical Belt. The N. Temperate Belt appears to have returned to the same latitude as in the early part of 1903.

I also measured the ratio between the equatorial and polar diameters on the photographs. The equatorial diameter is obviously affected by any trail of the image, however slight, during the exposure, which was in some cases as long as thirty or forty seconds. The polar axis was running rather jerkily, so that few of the images are good in this respect.

The mean value from my photographs was 1·000 : 1·084, as against Barnard's value of 1·000 : 1·069 ; but much better results will be obtained when the clock settles down.

Part III.—Satellite Observations.

These were carried on on the same lines as in previous years (*Monthly Notices*, vol. lxv. p. 696).

The result of the comparisons this year gives the relative brightness of the satellites as follows :

III = 1·02	II = 2·61
I = 2·16	IV = 3·96

These results seem to indicate a slight increase in the light of II. As far as I could judge, IV was, as a general rule, brighter and less bluish than in 1903–4, though still generally the faintest of the four.

The observations as regards colour, albedo, and variability are in complete agreement with those of 1903–4.

The distortion of the shadows near quadrature was well seen on several occasions.

Part IV.—General Remarks.

Cyclical variation in Period.—The observations this year have been too scanty to give good results, but when combined, in a few cases, with the published results of other observers they tend to confirm the conclusions I have already arrived at. The same holds good of the other two special points I referred to in my observations for 1903–4, viz. the *possible extension of the atmosphere of Jupiter* and the *visibility of the Red Spot bay.*

The value of a Driving-clock for delicate work.—The majority of the observations this year were made, as I have already mentioned, without a driving-clock. Hitherto I have regarded this adjunct as a luxury for visual work, but I am now convinced that it is an absolute necessity for the more delicate detail if the best work is to be done. The results this year are, I consider, less accurate than in previous years, and the fatigue to the eye is greatly increased by the strain of following a moving object. Even with the best slow motions there is a perceptible movement of the image when the screw is handled, and I have found it almost impossible to centre the fainter spots on the disc. The quantity as well as the quality of the observations has suffered owing to the number of fainter spots which have been missed. The average hourly number of transits taken this year was 15·8, as against 20 in 1903–4.

The Great S. Tropical Dark Area.—When the observations terminated abruptly in June this area was practically in conjunction with the Red Spot bay, the preceding end having passed the bay just before the observations began, and lying close to the zero meridian of system ii. The following end was still some distance following the bay, which shone up as a large white oval projected on the dark material. The area at the period covered a length of 70°–75° of longitude. I was prevented from watching the passage of the area further.

When next seen (in November) the dark area presented much the same appearance as in 1903–4, its total length being about 37°.

My observations of the preceding end, combined with published observations of Scriven Bolton and Flammarion, show a practically uniform period throughout the apparition, with a slight retardation to about the middle of October, followed by a slight acceleration.

Similarly the observations of the following end late in the apparition, combined with earlier observations of Flammarion, give a very uniform period of $9^h\ 55^m\ 20^s{\cdot}25$. Plotting this and prolonging it backwards, we get August 10 as the probable date of conjunction of the *following* end of the dark area with the *preceding* shoulder of the bay. Taking the observed positions of the following end of the area in June, and assuming the same period, we find that the following end should have reached the *following* shoulder also early in August, and would therefore

appear to have crossed the whole Red Spot bay (about 35° of longitude) almost simultaneously.

The same phenomena seem to have occurred at the last conjunction in 1902 July. As the preceding end of the area reached the following shoulder a dark wisp formed across the S. Tropical Zone at the preceding shoulder and moved down the zone at the normal speed of the dark area. As soon as the following end reached the following shoulder the dark area became complete on the other side of the bay, and moved off at its normal speed down the zone.

It seems impossible that there can be an instantaneous transference of material in this case from one side to the other of the bay, and some other explanation must be sought. The dark area seems to have passed neither *over* nor *under* the bay, but *round* it, by way of the S. Tropical Belt, completely skirting the oval of the bay without encroaching on it in any way. There seems to have been a progressive movement of material throughout the portion of the S. Tropical Belt south of the bay, the movement of the dark area into the belt following the bay causing the extrusion of an equal amount of dark material from the belt preceding the bay. The quantity of matter, so to speak, contained in the belt remained constant, while it acted almost like an incompressible fluid bounded rigidly by the oval of the Red Spot bay.

(This supposed action may be illustrated by taking a slightly curved tube, open at both ends, to represent the S. Tropical Belt at the Red Spot bay. The dark material may be represented by steel balls of such a size as to pass down the tube. If the tube be filled with steel balls and another ball be pushed into one open end, all the balls move, and one is pushed out of the other open end.)

Another peculiarity I have noticed with the dark area is its effect on the rotation-period of the dark "wave crests" in the S. Edge of S. Equatorial Belt and the intervening white spots. Before the formation of the dark area these markings had a period practically identical with that of the Red Spot; but since its formation (1901 May) their period has been very variable, being considerably retarded as the dark area approaches them, and accelerated directly after its passage, gradually returning to the normal. Their behaviour reminds me very much of the buoys in the Suez Canal during the passage of a large vessel. As the ship approaches the buoys are drawn in towards it, and after it has passed follow it as far as their mooring permits. If the moorings possessed considerable elasticity the analogy would be still more complete.

From a careful study of all the phenomena connected with the dark area, I am convinced that it is a well-defined mass of material moving with a high velocity through a slower current, but diverted and repelled in some mysterious way as it nears the Red Spot bay.

The true explanation of these phenomena would do much to increase our knowledge of the atmospheric conditions of *Jupiter*.

Visual Estimates versus *Micrometer Measures.*—There has been a good deal of controversy as to the relative values of these two methods of fixing the longitudes of the markings on *Jupiter*. Personally I am inclined to think that with small sharply defined markings there is little to choose between the two methods if employed by experienced observers. If the markings are very faint or very diffuse, I consider that eye estimates are more likely to give accurate results. Personally, with a micrometer, after taking every precaution as regards focus and parallax, I lose a delicate spot completely as soon as I try to place the wire on it, and I find the same difficulty with the fainter belts when taking measures for latitude.

One great cause of inaccuracy in visual work is, in my opinion, the use of an ephemeris calculated out beforehand for each spot. Each observation should be made perfectly independently without the slightest knowledge of the theoretical time of transit.

My own practice is to note the time of transit of *every* spot which can be seen with sufficient distinctness during the time of observation. The longitudes are never worked out till the transits are booked in the "transit ledger" (generally next day). By this means any possibility of bias is avoided. It is most important, however, as Stanley Williams has pointed out (*Zenographical Fragments*, vol. i. p. 4), that in visual observations the same eye should always be used, and that the line joining the eyes should be kept parallel to the direction of the belts. This, with a Newtonian with revolving head, can generally be easily arranged.

I hope that Professor Hough's strictures on eye estimates will not deter observers from pursuing this extremely valuable work.

TABLE I.

Average Rotation-periods in Different Zones.

Zone.	Approx. Latitude.	No of Spots.	Average No. of Obs.	Average Elapsed Rotations.	Rotation-period.
	°				h m s
White Spots. S. Temperate Zone (C)	−35	11	9·7	453	9 56 20·23
Dark Spots. S. Tropical Belt (D)	−28	2	9·5	583	9 55 27·78*
Dark Spots. S. Tropical Belt (D)	−28	7	17·9	472	9 55 20·63†
Red Spot	−15	3	19·0	672	9 55 40·00
Great S. Tropical Dark Area...	−21	4	26·5	612	9 55 20·95
Other spots in S. Tropical Zone (E) and S. Edge of S. Equatorial Belt (Fs) ...	−15 to −21	9	9·2	209	9 55 53·97

* Abnormal. † Normal.

TABLE II.

Latitudes of Belts from Measures.

	Distance from Centre of Disc at Mean Distance 5·20				
	(D) Centre of S Trop. Belt.	(Fs) S. Edge of S. Eq. Belt.	(Fn) N. Edge of S. Eq. Belt.	(L) Centre of N. Eq. Belt.	(N.) Centre of N. Temp. Belt.
Average of 5 Visual Measures ...	− 9·52	− 6·41	−3·00	+ 2·70	+ 8·72
Average of 7 Photographic Measures	− 9·70	− 7·12	−2·70	+ 2·68	+ 8·85
Mean ...	− 9·61	− 6·77	−2·85	+ 2·69	+ 8·78
Apparent latitude	−32°·33	−22°·13	−9°·13	+ 8°·60	+29°·25
Correction to centre at mean date (1905 March 4)	+ 2·74	+ 2·74	+2·74	+ 2·74	+ 2·74
True latitude (ϕ) ..	−29·59	−19·39	−6·49	+11·34	+31·99

The Annular Nebula in Lyra (*M* 57). By E. E. Barnard.

In *Monthly Notices* of the Royal Astronomical Society for 1900 January I have given a paper on the Annular Nebula of *Lyra* (*M* 57), in which it was shown that measures of the central star of the nebula with reference to a 12^m star (*a*) following, made by Professor Burnham in 1891, consistently differed from measures made by the writer in 1898 and 1899 by 1° in angle and 1″ in distance. The distance had apparently diminished, and it was there suggested that this difference might possibly be due to motion in the nebula.

Professor Asaph Hall had measured a number of small stars about the nebula in 1877 with reference to *a*. These stars were remeasured by me in 1899, but they did not indicate any motion in *a*; they seemed to be stationary, with the possible exception of the star *f*. Professor Hall did not see the central star, and hence there are no measures prior to those of Professor Burnham.

In 1900 February Professor Scheiner and I measured at Potsdam a negative made by Dr. Scheiner in 1894 October 29 (see *Monthly Notices*, January 1900, p. 257), which gave results that did not verify the suspected change in the position of the nucleus.

In 1900 September Professor F. P. Leavenworth, of the University of Minnesota, measured these stars and the nucleus on several negatives taken by him in 1897–1900 (see *Monthly Notices*, vol. lxi. p. 25).

In 1902 Mr. Burt L. Newkirk, of Minneapolis, from all the measures, determined the proper motion and the parallax of the

nebula in an inaugural dissertation for the Doctor's degree at Munich—"Eine Untersuchung der Parallaxe des Zentralsternes des Ringnebels in der Leier" (Munich, 1902).

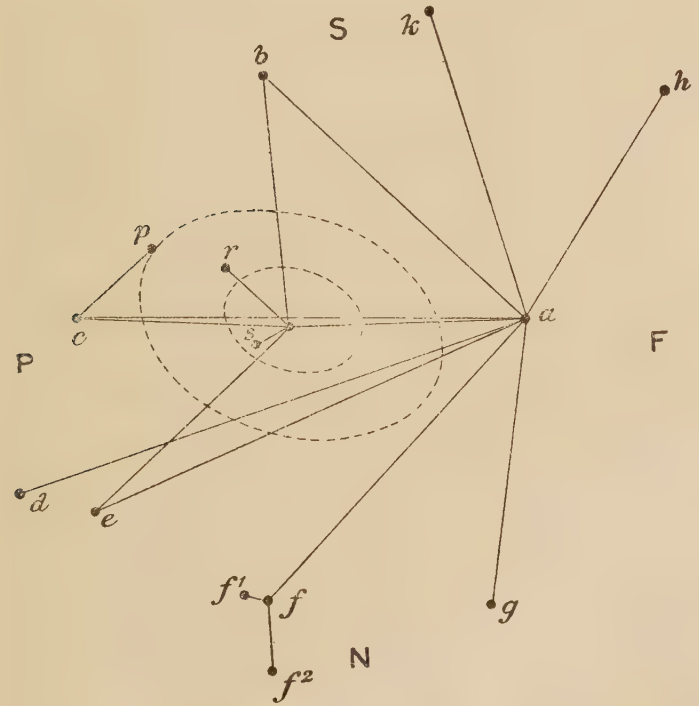
For the proper motion of the central star Dr. Newkirk got the values

$$\Delta\alpha = -0^{s}\cdot012 \pm 0^{s}\cdot0012$$
$$\Delta\delta = +0''\cdot10 \pm 0''\cdot029.$$

These would give the following for the direction and amount of the annual motion of the central star :

Direction of motion	pos. ang.	303°·7
Amount	„	0″·180.

Dr. Newkirk found for the parallax a value of 0″·10.



As this was the first nebula whose distance and proper motion had ever been determined it became of the greatest importance to verify the results.

To strengthen the value of the measures made by me in 1898–9 I have recently measured two photographs of the nebula

which I made with the 40-inch telescope and a colour-screen on 1900 September 2 and September 3. These agree quite closely with the visual measures, and give a good foundation for the comparison of any measures made hereafter.

Sufficient time having elapsed to test the above results, in 1903 and 1904 I again measured the position of the nucleus with respect to *a*. According to Dr. Newkirk's value of the motion the total displacement of the nucleus in the five years that had elapsed would be 0″·90 ; and in the direction of *a* the displacement would be 0″·75, which would be easily measurable. It will be noticed that the direction of motion given by Dr. Newkirk would increase the distance from the star *a*, which cannot be reconciled with the early and late measures of the distance from the nucleus to *a*.

The results from these measures of 1903–4 do not verify the motion derived by Dr. Newkirk. They seem to imply that there has been no measurable change in the position of the nucleus or central star, and they certainly show that the relatively large motion assigned it does not exist. Dr. Newkirk's motion lies nearly in the direction of the star *e*, and to further test his values I have recently made on two nights measures of the position-angle and distance of *e* from the nucleus. This distance should have diminished an entire second of arc, but the measures show no certain change.

As Dr. Newkirk's parallax for the central star depends upon the proper motion which he determined, and which is shown not to exist, the parallax itself must be fallacious.

The discordance in the position of the star *f* as measured by Professor Hall and myself led me to suppose that *f* had a small proper motion, but the measures of the present year show that there is no definite motion even in this star. Indeed, everything in the immediate region of this nebula seems to have the usual fixity of the ordinary small stars.

In the paper for *Monthly Notices* for 1900 January, p. 250, attention was called to a 17^{m} star which was at the limit of the 40-inch visually, and which I could not measure. On 1900 July 29, with good seeing, this star could be seen very steadily. If necessary, its position could have been measured readily. This star should not, therefore, be considered as the limit of the 40-inch visually under good conditions. On this same occasion I could see the second star inside the ring. It was north preceding the nucleus, and was estimated to be $8\frac{1}{2}''$ distant in the direction of the star *d*, or in position-angle 300°±. This agrees closely with the position subsequently measured on the photographs. At this time the central star was bright and easy, and was estimated to be 13 magnitude.

Conditions of steadiness make a very great difference in the visibility of a faint star in a large telescope. The difference is still greater if the star happens to be immersed in nebulosity.

On the two photographs of 1901 September 2 and September 3

I have measured the position of this second star in the ring, and also another star on the inner edge of the preceding part of the ring. This last star could be measured on only one plate.

Measures of the Photographs.

Nucleus and *a*.

Sept. 2	1901·671	88° 55′	60″·73
3	·673	89 01	60·56
	1901·67	88 58	60·64

Nucleus and *b*.

Sept. 2	1901·671	185° 21′	64″·98
3	·673	185 21	64·87
	1901·67	185 21	64·92

Nucleus and *c*.

Sept. 2	1901·671	268° 22′	54″·83
3	·673	268 17	54·84
	1901·67	268 19	54·83

Nucleus and *e*.

Sept. 2	1901·671	312° 50′	71″·14
3	·673	312 49	71·12
	1901·67	312 49	71·13

a and *b*.

Sept. 2	1901·671	225° 28′	93″·71
3	·673	225 21	93·79
	1901·67	225 25	93·75

a and *c*.

Sept. 2	1901·671	268° 39′	115″·58
3	·673	268 40	115·31
	1901·67	268 39	115·45

a and *d*.

Sept. 2	1901·671	286° 42′	137″·29
3	·673	286 47	137·30
	1901·67	286 45	137·30

a and *e*.

Sept. 2	1901·671	292° 46′	122″·38
3	·673	292 40	122·33
	1901·67	292 43	122·35

a and *g*.

Sept. 2	1901·671	350° 28′	76″·31
3	·673	350 28	76·21
	1901·67	350 28	76·26

a and *f*.

Sept. 2	1901·671	314° 53′	99″·84
3	·673	314 47	99·88
	1901·67	314 50	99·86

f and f_1.

Sept. 2	1901·671	261° 11′	4″·98
3	·673	262 12	4·93
	1901·67	261 41	4·95

f and f_2.

Sept. 2	1901·671	3° 08′	18″·19
3	·673	3 22	18·15
	1901·67	3 15	18·17

a and *h*.

Sept. 2	1901·671	148° 16′	70″·73
3	·673	148 10	70·82
	1901·67	148 13	70·77

a and *k*.

Sept. 3	1901·673	195° 56′	84″·71

c and *p*.

Sept 2	1901·671	133° 48′	27″·41
3	·673	133 41	27·53
	1901·67	133 45	27·47

Nucleus and *s*.

Sept. 2	1901·671	300° 36′	10″·23
3	·673	300 44	10·31
	1901·67	300 40	10·27

Nucleus and *r*.

Sept. 3	1901·673	223° 31′	21″·83

The exposure times for these photographs were

1901	h	m		h	m	
Sept. 2	19	40	to	23	15	Sid. time
„ 3	8	30	„	11	40	Central standard time.

These plates were measured on a Gaertner Measuring Machine, with which position angles and distances can be determined. When they were originally made no such machine was available.

On the plate of September 3 *Atlas* and *Pleione* and *Electra* and *Celæno* of the *Pleiades* were allowed to trail. A few short exposures on these stars were also impressed on the same plate, which remained undisturbed in the telescope. From these the parallel and scale values were determined in the measuring machine, and were used for the reduction of the measures. The parallel in the plate of September 2 was determined by a comparison of the known angles obtained from the other plate. These measures are therefore entirely independent of the micrometer of the 40-inch.

As the two photographs were made with a yellow colour screen and Cramer Instantaneous Iso plates the magnitudes of the small stars on the plate will not be very different from what they are visually. I have thus compared several of the stars in the nebula with some of those outside, whose magnitudes I had already estimated (*Monthly Notices*, vol. lx. p. 248).

Following are the magnitudes thus derived :—

p =	14m·8	from comparisons with	6	different stars
s =	14·2	„ „	3	„
r =	14·7	„ „	3	„
nucleus =	13·6	„ „	9	„

Hence none of these stars would be difficult if free from the nebula.

The measures made in 1903 and 1904, especially the distances, are not very accordant. Good nights could not be selected for the work, and the nucleus was measured at times when the seeing was so bad that the measures should not have been made. There are enough observations, however, to eliminate the effect of poor

seeing, and I think the mean results are satisfactory. No observation has been rejected. On two dates the nucleus could not be seen after the angles were measured, and the distances could not be obtained.

These observations follow :—

Nucleus and *a*.

(1903).

July 21	1903·552	88°44	59″83
27	·569	88·40	...
Aug. 10	·607	89·01	60·50
11	·610	88·94	60·36
17	·626	88·91	60·65
18	·629	88·35	60·89
24	·645	89·02	61·30
31	·664	89·65	60·73
Sept. 1	·667	88·71	60·35
7	·684	88·82	60·67
21	·722	88·79	60·86
22	·725	88·74	60·68
28	·741	88·86	61·22
Oct. 13	·782	88·84	61·30
27	·821	88·52	60·88
	1903·669	88·80	60·73

(1904).

Apr. 26	1904·319	89°17	61″39
May 17	·376	89·35	60·73
June 14	·453	89·07	61·08
July 9	·521	88·66	60·67
Aug. 1	584	88·48	...
26	·653	88·69	60·52
	1904·484	88·90	60·88

Following are the measures made in 1905 :—

Nucleus and *e*.

Nov. 26	1905·904	312°87	71″38
28	·909	312·85	70·91
	1905·91	312·86	71·14

a and *f*.

Nov. 26	1905·904	314°·78	100″·08
28	·909	314·75	100·11
	1905·91	314·76	100·09

f and f_1.

Nov. 28	1905·909	258°·32	5″·15

In these observations the conditions were very poor, and the nucleus was very difficult. The images of *f* and f_1 were very much blurred, and the measures difficult and uncertain.

Following is a collection of all the measures of the nucleus and of the small stars near the nebula that are known to me :—

Nucleus and *a*.

Burnham	1891·45	87°·8	61″·69	(5n)
Scheiner and Barnard	1894·83	88·92	60·71	(1n) photo
Barnard	1898·60	88·77	60·70	(5n)
Barnard	1899·48	89·14	60·66	(5n)
Leavenworth ...	1899·55	89·29	60·56	(4n) photo
Barnard	1901·67	88·96	60·64	(2n) photo
Barnard	1903·67	88·79	60·73	(15–14n)
Barnard	1904·48	88·90	60·88	(6–5n)

Nucleus and *b*.

Barnard	1899·58	185°·37	65″·04	(3n)
Leavenworth ...	1899·84	186·61	65·17	(1n) photo
Barnard	1901·67	185·35	64·92	(2n) photo

Nucleus and *c*.

Barnard	1899·53	267°·59	54″·92	(3n)
Leavenworth ...	1900·13	268·82	55·34	(2n) photo
Barnard	1901·67	268·32	54·84	(2n) photo

Nucleus and *e*.

Barnard	1899·49	312°·38	70″·96	(3n)
Leavenworth ...	1899·55	312·80	71·32	(4n) photo
Barnard	1901·67	312·82	71·13	(2n) photo
Barnard	1905·91	312·86	71·14	(2n)

a and *b*.

Hall	1877·6	225°·5	93″·90	(2n)
Barnard	1899·51	225·76	93·58	(3n)
Leavenworth ...	1899·84	225·57	94·38	(1n) photo
Barnard	1901·67	225·41	93·75	(2n) photo

a and *c*.

Hall	1877·6	268°·0	115″·83	(2n)
Barnard	1899·50	268·78	115·58	(3n)
Leavenworth ...	1900·13	268·63	115·55	(2n) photo
Barnard	1901·67	268·66	115·44	(2n) photo

a and *d*.

Hall	1877·6	286°·9	138″·58	(2n)
Barnard	1899·50	286·96	137·60	(4–3n)
Leavenworth ...	1900·17	286·76	137·44	(3n) photo
Barnard	1901·67	286·74	137·30	(2n) photo

a and *e*.

Hall	1877·6	292°·6	122″·90	(2n)
Barnard	1899·47	292·81	122·13	(2n)
Leavenworth ...	1899·55	292·71	122·37	(4n) photo
Barnard	1901·67	292·72	122·35	(2n) photo

a and *g*.

Hall	1877·6	350°·5	77″·18	(2n)
Barnard	1899·51	350·78	76·16	(4n)
Leavenworth ...	1900·17	350·32	76·46	(3n) photo
Barnard	1901·67	350·47	76·26	(2n) photo

a and *f*.

Hall	1877·6	313°·7	101″·79	(2n)
Barnard	1899·50	315·39	99·97	(2n)
Barnard	1901·67	314·83	99·86	(2n) photo
Barnard	1905·91	314·76	100·08	(2n)

f and f_1.

Hall	1877·6	253°·3	3″·96	(2n)
Barnard	1899·53	262·95	4·89	(3n)
Barnard	1901·67	261·69	4·95	(2n) photo
Barnard	1905·91	258·32	5·15	(1n)

f and f^2.

Hall	1877·6	4°·8	17″·31	(2n)
Barnard	1899·52	3·42	17·86	(2n)
Barnard	1901·67	3·25	18·17	(2n) photo

a and *h*.

Barnard	1899·47	148°·14	70″·52	(3n)
Leavenworth ...	1899·55	148·59	70·42	(4n) photo
Barnard	1901·67	148·22	70·77	(2n) photo

a and *k*.

Barnard	1899·59	195°·86	85″·16	(5n)
Barnard	1901·67	195·93	84·71	(1n) photo

c and *p*.

Barnard	1899·52	133°·34	27″·24	(2n)
Barnard	1901·67	133·74	27·47	(2n) photo

Nucleus and *s*.

Barnard	1901·67	300°·66	10″·27	(2n) photo

Nucleus and *r*.

Barnard	1901·67	223°·52	21″·83	(1n) photo

Nucleus and *d*.

Leavenworth ...	1900·17	299°·78	81″·97	(3n) photo

Nucleus and *g*.

Leavenworth ...	1900·17	32°·50	90″·13	(3n) photo

Nucleus and *h*.

Leavenworth ...	1899·55	121°·18	113″·84	(4n) photo

As stated in my previous paper, *Monthly Notices*, vol. lx. p. 252, the final reduction of all the measures of the micrometer screw gave a less value for it than was used in my previous measures. The present observations are reduced with the adopted value of 9″·665. Where my former measures are quoted in the present paper they have been re-reduced with the above value of the screw.

Yerkes Observatory, Williams Bay, Wis.:
1905 *December*.

Elements and Light Curve of RV Lyræ (Ch. 6915).
By A. Stanley Williams.

R.A. = 19h 10m 49s Decl. = +32° 10′·1 (1855)
„ = 19 12 31 „ = +32 14·8 (1900)

Preliminary elements of variation of this Algol-type variable were published in the *Astronomische Nachrichten*, No. 3811, the period being there given as $3^{d}\cdot598883$. The minima of this star are rather faint for observation with a $6\frac{1}{2}$-inch aperture, but observations have been made here whenever practicable; and although the results are neither so numerous nor so satisfactory as might be wished, yet it now seems desirable to discuss the results so far obtained, and to derive improved elements of variation, particularly since it is now practicable to connect the more recent observations with an early Harvard College photographic one.

Table I. contains the comparison stars employed and the adopted light-scale. The latter is a somewhat provisional one, as a complete discussion of the results is reserved to the time when more observations are available; but it appears to be quite satisfactory, and it does not seem likely that any material modification will be made hereafter. The magnitudes in the fifth column of the table are based on the assumptions that the magnitude of the star A is 8·61, and the value of a step 0·05 magnitude. The star *f*, it may be mentioned, is just clearly and steadily visible on a clear night in a $6\frac{1}{2}$-inch reflector.

Table I.

Comparison Stars and Light-scale.

Star.	B.D. No.	B.D. Mag.	Light.	Adopted Mag.
A	+32°·3376	9·2	0·0	8·61
B	+32·3377	9·1	14·2	9·32
C	+32·3380	9·4	26·7	9·94
b	...	...	41·2	10·67
c	...	...	63·6	11·79
d	...	...	63·6	11·79
e	...	...	72·6	12·24
f	...	...	78·2	12·54

The comparison stars are shown in the adjoining little chart based on the B.D. and constructed for 1855. It should be mentioned that the fainter stars have only been inserted by estimation from a photograph, but the positions will probably be sufficiently accurate for the purpose of identification.

Table II. contains the observed heliocentric Greenwich mean times of minimum.* The last eleven of these have been derived from the visual observations by means of a mean light-curve. The weights in the last column are on a scale ranging from 1 to 5. A weight 5 implies that the observations are numerous, very accordant, and distributed pretty uniformly on either side of the minimum. The time of the observation of 1901 October 7 was derived from a photograph obtained here with a 4·4-inch portrait lens, on the assumptions that the photographic light-curve and the photographic brightness of the variable and of the comparison star *c* respectively are the same as the visual ones. On the photograph the variable is equal in brightness to this star *c*. Particulars of an early Harvard College photograph, showing the

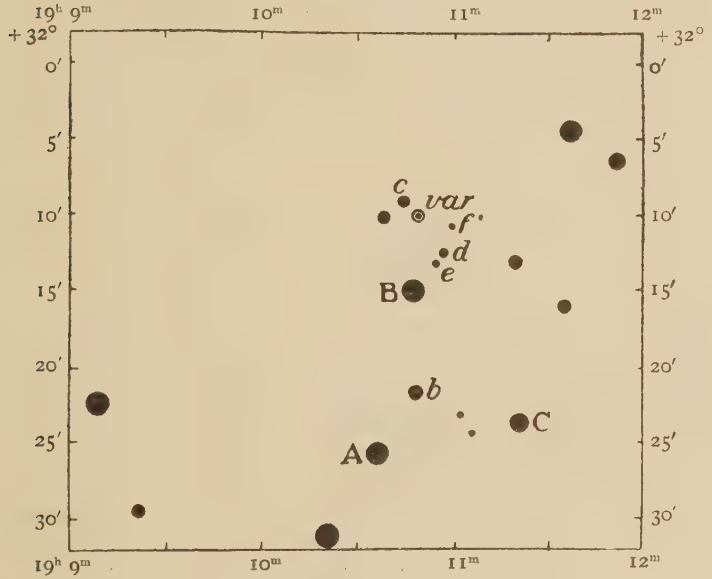


Chart of the Region of *RV Lyræ*.

variable faint, have been given by Professor E. C. Pickering in H.C.O. Circular, No. 66 (*A.N.* 3833). A preliminary discussion of the observations showed that this photograph must have been taken when the star was increasing in brightness, and the first minimum of the table was assumed to have occurred $3^h\ 30^m$ earlier than the time given for the photograph.

* In addition to the minima contained in the table Dr. E. Hartwig observed the star decrease 1·3 mag. between $9^h\ 22^m$ and $11^h\ 19^m$ (Bamberg mean time) on the night of 1902 Aug. 16 (*A.N.* 3811). The computed time of minimum is $12^h{\cdot}05$ G.M.T. = $12^h\ 49^m$ Bamberg mean time.

TABLE II.

Observed and Computed Times of Minimum.

E.	Observed Minimum.					Computed Minimum.	O—C.	wt.
				h	m	J.D. 241+	m	
−836	1893	July	11	14	44·9	2658·6145	2656·6148	− 0·4	ph.
0	1901	Oct.	7	9	21·8	5665·3901	5665·3897	+ 0·6	ph.
67	1902	June	5	11	45·8	5906·4902	5906·5236	−48·1	1
77		July	11	12	16·9	5942·5117	5942·5137	− 2·9	4
79		,,	18	17	01·9	5949·7096	5949·7117	− 3·0	2
82		,,	29	12	04·8	5960·5034	5960·5088	− 7·8	4
92		Sept.	3	11	45·2	5996·4897	5996·4989	−13·2	4
167	1903	May	31	10	19·5	6266·4302	6266·4249	+ 7·6	3
197		Sept.	16	9	32·3	6374·3974	6374·3953	+ 3·0	3
289	1904	Aug.	12	12	21·3	6705·5148	6705·5045	+14·9	5
297		Sept.	10	7	19·8	6734·3054	6734·2966	+12·7	1
299		Sept.	17	12	10·3	6741·5071	6741·4946	+18·0	1
369	1905	May	27	10	19·3	6993·4301	6993·4255	+ 6·6	2

The following are the fresh elements of variation.

$$\text{Minimum} = 1901\ \text{Oct.}\ 7,\ 9^{h}\ 21^{m}\cdot2\ (\text{G.M.T.}) + 3^{d}\ 14^{h}\ 22^{m}\ 34^{s}\cdot7\text{E}$$
$$= \text{J.D.}\ 2415665\cdot3897 + 3^{d}\cdot599013\ \text{E}$$

The computed times of minimum and the differences O—C will be found in the last two columns of the above table. These differences are not particularly large with the exception of that for 1902 June 5 ; but with regard to this it should be remarked that on the night in question only two glimpses of the star could be obtained through nearly continuous cloud, and that since these two glimpses, separated by an interval of 16^{m}, seemed to show that the variable was then decreasing in brightness, whereas it must actually have been increasing, it is probable that one if not both of the observations were more or less affected by cloud.

But the grouping of the plus and minus differences in the table appears to indicate either the existence of systematic error in the observations or else that the adopted period is a little too short. As regards the latter, however, it does not seem permissible to make the time of minimum on 1893 July 11 any earlier than that which has been adopted, so that this early Harvard photograph appears to be conclusive against the adoption of a longer period. The star was assumed to be $3^{h}\ 30^{m}$ past minimum at the time of the photograph, and if the time of minimum were put any—even a few minutes—earlier, the star would only have been very slightly fainter than normal. There is, however, a cause which might have produced a systematic

discordance such as that shown. The mean light curve from which all the times of minimum were derived was constructed from the observations of 1902, and on the assumption that the increasing phase corresponded to the decreasing phase, for nearly all the observations of any value up to that time had been made when the star was decreasing in brightness. But it will be seen from the mean light curve in Table III. that the increasing phase lags a little behind the decreasing one. Now the minima subsequent to 1902 were chiefly observed only in the increasing phase, that of 1904 September 17 being the only one observed during the decreasing phase alone.* Hence it will be evident that the result of using this mean light curve will be to make these subsequent minima, observed chiefly in the increasing phase, a little later than those of 1902, which were observed chiefly only in the decrease. In order to test this point the times of minimum were redetermined by means of the light curve in Table III., the corrections to the times in Table II. being as under :

Date of Minimum.	Correction.	Date of Minimum.	Correction.
	m		m
1902 June 5	+6	1903 May 31	− 5
July 11	+3	Sept. 16	0
„ 18	−4	1904 Aug. 12	− 9
„ 29	−1	Sept. 10	+ 2
Sept. 3	−1	„ 17	−11
		1905 May 27	− 3
Mean	$= +0^m\cdot6$	Mean	$= -4^m\cdot3$

The mean correction indicated for the five minima of 1902 is $+0^m\cdot6$, and that for the six subsequent minima is $-4^m\cdot3$. Hence there is a difference of about five minutes in the right direction. The whole of the systematic difference shown by Table II. does not appear, however, to be accounted for in this manner, so that it seems possible that the real period may be very slightly longer at present than that adopted. Unfortunately the observations of this variable have been almost a complete failure during the present year, owing to unfavourable weather, so that it does not seem safe to conclude anything more definite at present.

The mean light curve given in Table III. has been derived from 92 *good* observations, all doubtful ones having been rejected. It appears to be quite reliable and satisfactory excepting just at the beginning of the decrease and at the end of the increase, where the observations are at present only few in number, so that the exact form of the curve at these two points is somewhat uncertain.

* The minimum of 1904 Aug. 12 was observed during both the decrease and the increase.

TABLE III.

Light Curve of RV Lyræ.

Time.	Brightness Before Min.	Brightness After Min.	Time.	Brightness Before Min.	Brightness After Min.
h m			h m		
4 00	49·0	50·6	1 50	74·5	76·7
3 50	49·5	52·0	1 40	76·0	77·9
3 40	51·0	53·6	1 30	77·5	79·0
3 30	53·2	55·6	1 20	78·7	79·9
3 20	55·4	57·7	1 10	79·7	80·7
3 10	58·0	59·9	1 00	80·5	81·2
3 00	60·5	62·5	0 50	81·1	81·6
2 50	62·6	64·7	0 40	81·7	82·0
2 40	65·3	67·0	0 30	82·0	82·1
2 30	67·4	69·3	0 20	82·2	82·2
2 20	69·2	71·4	0 10	82·3	82·3
2 10	71·2	73·5	0 00	82·4	82·4
2 00	72·8	75·1			

The brightness of the variable according to the light-scale of Table I. is given for every ten minutes of time before and after minimum in the above table. The normal brightness of the star is 49·0 of the scale, corresponding to 11·06 mag. The minimum brightness is 82·4 = 12·73 mag. There is no stationary period at minimum. The table shows a slight though distinct difference in the form of the curve before and after minimum. The star appears to take a little longer in recovering its light than it did in losing it. The difference is, however, not great, and may perhaps be only subjective.

Hove: 1905 *December* 26.

Elements and Light Curve of VW Cygni (Ch. 7268).
By A. Stanley Williams.

R.A. = 20 09 37 Decl. = +34° 03′·7 (1855)
„ = 20 11 21 „ = +34 11·8 (1900)

Preliminary elements of variation of this Algol-type variable star have been published in the *Astronomische Nachrichten*, No. 3899, the period being there given as 8·4326 days. The minima of this star are difficult to observe, owing to the long duration of the stationary period (7 hours). In fact I have not

yet been able to observe a minimum in a complete manner; that is, to observe both the decreasing and increasing phases on the same night. Hence an outline of the manner in which the improved elements of variation and the light curve have been derived may not, perhaps, be without interest.

The comparison stars used and the adopted light scale are given in Table I., together with the assumed stellar magnitudes of the stars, based or the assumptions that the star *a* is 8·2 mag. and the value of a step is 0·05 mag. The adjoining little chart

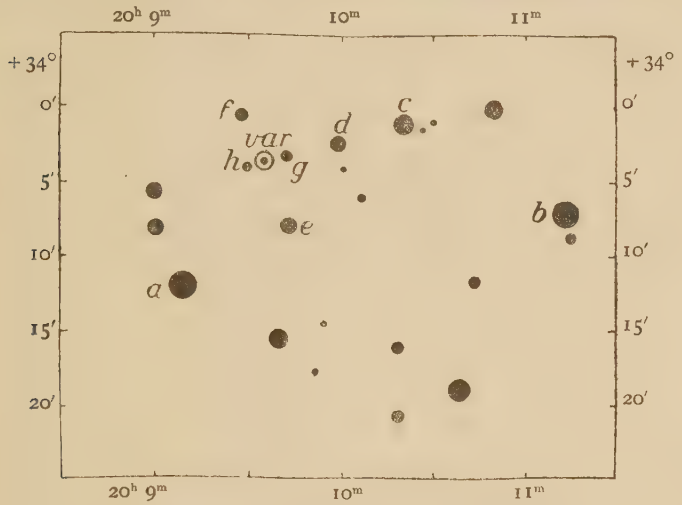


Chart of the Region of *VW Cygni*.

(for 1855) will assist in identifying the comparison stars and the variable. The fainter stars have, however, only been inserted in this by estimation.*

TABLE I.

Comparison Stars and Light Scale.

Star.	B.D. No.	B.D. Mag.	Light.	Assumed Mag.
a	+34°3936	8·5	80·0	8·20
b	+34·3953	8·7	65·8	8·91
c	+34·3946	9·2	52·3	9·58
d	+34·3942	9·5	41·8	10·11
e	...	...	37·8	10·31
f	...	...	26·5	10·87
g	...	...	12·5	11·57
h	...	...	2·5	12·07

* The B.D. positions of two or three of the stars shown on the chart are apparently slightly in error. In particular the B.D. declination of the star *c* would appear to be about $\frac{2}{3}'$ too small, and that of the star *d* about $\frac{2}{3}'$ too large.

There are eight minima available for the purpose of deriving an improved value of the period of variation.* On two nights the star was observed during the decreasing phase, and on the remaining six nights during the increasing phase. Since the star was never observed during both phases on the same night, it is impossible to determine the point of minimum, or the middle of the stationary period, directly from the observations. As there is an interval of only two periods between the two observations of the decreasing phase, these two observations are of little use for determining the period of variation. It was necessary, therefore, to rely in the first place upon the six observations of the increasing phase. A rough† light curve (Curve A) had already been formed from the early observations of 1903, and by means of this curve the times (T_2) when the variable was of brightness 20 on the light scale of Table I. were carefully determined. This brightness 20 was chosen because it was roughly near the average brightness of the observations made during the increasing phase. The times (T_1) when the variable was of corresponding brightness were also determined for the two minima observed during the decreasing phase. Table II. contains the observed times of T_2.

TABLE II.

Observed and Computed Times of T_2.

E.	Observed T_2.	Computed T_2.	O−C.
			d
80	J.D. 2416340·39	6340·379	+0·011
89	6416·24	6416·255	− ·015
115	6635·44	6635·450	− ·010
124	6711·34	6711·326	+ ·014
173	7124·43	7124·425	+ ·005
175	7141·28	7141·286	− ·006

The above observations on a least-square reduction gave $8^d{\cdot}4306$ as the corrected period of variation. The computed times of T_2 and the residuals O − C will be found in the table. The mean of the times T_2 is J.D. 2416728·187. The two observations of T_1 were then reduced to the same date, the mean of the two being J.D. 2416727·759. The mean of the times T_1 and T_2 was assumed to be the time of minimum, so that the improved elements (Elements II.) reduced to E = 0 are :

$$\text{Minimum} = \text{J.D. } 2415665{\cdot}717 + 8^d{\cdot}4306\ \text{E}$$

* Four observations made during the minimum which occurred on the night of 1903 September 7 are of no use for this purpose, since they all relate to the long stationary period.

† This curve differs only slightly from the light curve (C) contained in Table III.

All the good * observations (60 in number) made when the star was below normal brightness were then reduced with these elements, and a fresh light curve (B) drawn on the assumption that the increasing and decreasing phases were exactly similar. This was rendered necessary owing to the fact that there are still two considerable gaps where there are no observations available. But it appeared that the observations would be somewhat better represented by a slight departure from exact similarity in the increasing and decreasing phases, and a few local corrections were accordingly made, resulting in the third light curve (C), which is given in Table III., where the brightness of the star is stated according to the light-scale of Table I. for every half-hour before and after minimum.

TABLE III.

Light Curve of VW Cygni.

Time.	Brightness.		Time.	Brightness.	
	Before Min.	After Min.		Before Min.	After Min.
h m			h m		
10 30	45·2	45·2	5 00	19·6	20·0
10 00	45·0	45·0	4 30	15·8	16 1
9 30	44·0	43·0	4 00	11·7	11·9
9 00	42·0	41·0	3 30	6·5	6·5
8 30	39·5	39·0	3 00	6·5	6·5
8 00	37·0	37·0	2 30	6·5	6·5
7 30	34·4	34·8	2 00	6·5	6·5
7 00	31 8	32·6	1 30	6·5	6·5
6 30	29·0	30·0	1 00	6·5	6·5
6 00	26·1	27·0	0 30	6·5	6·5
5 30	23·0	23·5	0 00	6·5	6·5

The above light curve must be very near the true one, though there are no observations at present during the first part of the decrease and again at the end of the stationary period and the commencement of the increase. The middle point of the stationary period has been assumed to be the minimum point, and the times of minimum † have been determined by means of the above light curve, and are given in Table IV.

* A few observations made under unfavourable circumstances were rejected.

† These are geocentric Greenwich mean times, the correction for the light equation not having been taken into account in the present investigation.

TABLE IV.

Observed and Computed Times of Minimum.

E.	Observed Minimum.				Computed Minimum.	O−C.
		d	h m	J.D. 241 +		h m
0	1901 Oct.	7	13 28	5665·561	5665·7220	(−3 52)
79	1903 Aug.	4	17 39	6331·735	6331·7394	− 6·3
80		13	4 13	6340·176	6340·1700	+ 8·6
81		21	14 20	6348·597	6348·6006	− 5·2
89	Oct.	28	0 53	6416·037	6416·0454	− 12·1
115	1904 June	3	5 44	6635·239	6635·2410	− 2·9
124	Aug.	18	3 17	6711·137	6711·1164	+ 29·7
173	1905 Oct.	5	5 05	7124 212	7124·2158	− 5·5
175		22	1 44	7141·072	7141·0770	− 7·2

The period of variation was then redetermined from the observed times of minimum, the finally adopted elements of variation (III.) being as under:

$$\text{Minimum} = 1901 \text{ Oct. } 7,\ 17^h\ 20^m \text{ (G.M.T.)} + 8^d\ 10^h\ 20^m\ 04^s\ E$$
$$= \text{J.D. } 2415665{\cdot}722 + 8^d{\cdot}4306\ E$$

There is no difference from the elements II. so far as the length of the period is concerned, and only a slight shift in the epoch of minimum. The computed times of minimum and the residuals O−C will be found in the table. The residuals seem to be quite satisfactorily small, considering the circumstances of the case.

The observation of 1901 October 7 is a photographic one. The star must have been at or very near its minimum brightness at the time of this photograph, but owing to the long duration of the stationary period this observation is of no use for correcting the elements, beyond showing that the period can hardly be any shorter than that adopted.

The normal brightness of the variable is 45·2 of the light scale = 9·93 mag., and the minimum brightness 6·5 = 11·87 mag. The duration of the stationary period is $7^h\ 0^m$, and the whole duration of the eclipse phase $20^h\ 30^m$. The long duration of the stationary period is somewhat interesting, and it would seem that one of the two component bodies is both larger and fainter than the other one. There is no indication of the existence of any secondary minimum.

Hove: 1905 *December* 26.

On a Method of Determining the Absolute Dimensions of an Algol Variable Star. By Alex. W. Roberts, D.Sc.

I. *Introduction.*

The present paper deals with an extension of the problem of Algol variation in the direction of a determination of the absolute dimensions of a close binary star.

Although the more definite and more accurate consideration of the dimensions of such systems falls more properly within the area of spectroscopic research, yet, theoretically at least, the light-curve of any eclipse variable exhibits data which when properly discussed yield a determination of the absolute size of the system.

The theory that underlies this important determination is the simple one that light takes an appreciable interval of time to traverse the orbit of a binary star.

A moment's reflexion will make it evident that this circumstance must make itself manifest as an acceleration in the apparent occurrence of both the primary and secondary maximum phases. The time of passing the primary and secondary maxima will, however, remain unchanged; that is, the approach and recession of the component stars relative to the Earth as they revolve round one another will be translated, owing to the measurable velocity of light, into a corresponding hastening and retardation of the successive phenomena of eclipse.

It will be clear, therefore, that if we had the means of ascertaining the light-curve of an Algol variable with perfect precision and completeness, and if all the phenomena of eclipse were capable of geometrical explanation and exposition, then, at all times, the light-curve of the system under consideration would provide sufficient data for a definite determination of the absolute dimensions—size, mass, and density of the eclipsing stars.

It will require little acquaintance with the many perplexities of variable star curves to assure one that, while in theory the problem of determining the dimensions of a binary star from an examination of its light changes has the merit of simplicity, in actual practice the solution is one beset with difficulties and obscured by uncertainties.

(1) It is not possible to determine the light-curve of a close binary star with the accuracy and refinement necessary for a numerical solution of the problem, except in cases where the variable completes its full period in a few hours.

In the latter circumstance the intervals between the four cardinal phases of variation, principal minimum, principal maximum, secondary minimum, secondary maximum, can be determined to within a minute of time. This is a quantity sufficiently refined to indicate, at least, a major limit to the size of the star.

(2) If all the phenomena of variation are to be included in a

consideration of the problem, and any system of exclusion must weaken the weight of the solution, then we must travel beyond the simple facts of eclipse to a region of physical causes and conditions to find a complete explanation of their origin and an interpretation of their character. We must, for instance, take into account the ever-changing figure of the component stars, due to eccentricity of orbit, as well as their rhythmic fluctuations in brightness, consequent on alterations in surface-pressure and tension.

(3) A number of untenable assumptions have always to to be made regarding the form and surface brightness of the component stars.

Notwithstanding these hindrances to a hopeful dealing with the question of the dimensions of an Algol variable, it seemed to me worth while instituting an inquiry as to the extent and nature of the uncertainty which must surround a solution so conditioned as that already indicated in the preceding paragraphs. I accordingly, early in 1905, worked out a graphical solution of the problem, taking the Lovedale observations of Algol variables as the materials of my investigation.

To my surprise the results obtained were much more definite than I had expected. They were, indeed, sufficiently final in character to convince me that in certain cases—*i.e.* rapidly varying stars—the problem admitted of a definite and reliable solution.

Lest my own observations, obtained by the method of sequences, might contain within them some systematic error leading to a false result, I asked Professor Pickering to permit me to make use of the very fine series of observations of the rapidly varying star *U Pegasi* made by Professor O. C. Wendell with the Harvard Meridian Photometer. With his usual kindness Professor Pickering at once sent me the whole of Professor Wendell's observations of *U Pegasi*.

I think it will be regarded as a sufficiently complete exposition of the problem we are considering if at this stage of its development we simply deal with two suitable stars, one in the northern hemisphere and one in the southern hemisphere.

The northern variable star *U Pegasi*, both because of its rapid period and because of the fulness and accuracy with which its light-curve has been determined by Professor Wendell, presents a very favourable object for the investigation we have in purpose.

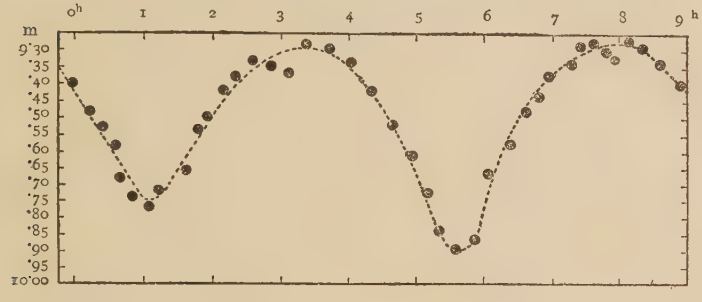
Then among southern stars over 10,000 observations have been secured of *RR Centauri*, the mean light-curve resulting from this mass of detail being sufficiently refined to warrant an inquiry regarding the absolute dimensions of the system.

The mode of observing both stars is so different in principle and in art that the possibility of a common systematic error, personal or instrumental, influencing the observations is remote.

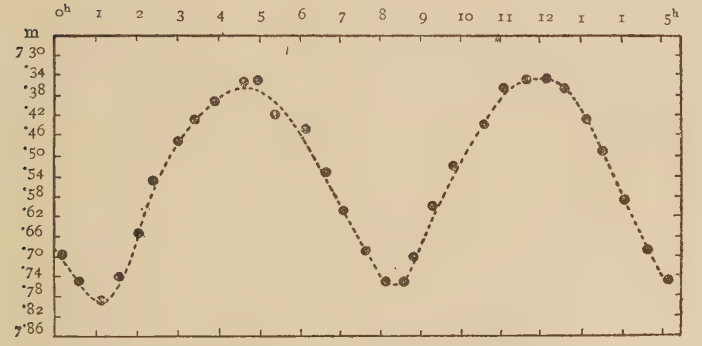
II. *Statement of the Problem.*

In the two following figures are given the light-curves of *U Pegasi* and *RR Centauri* respectively.

Before dealing directly with the relation which exists between the velocity of light and certain portions of the unsymmetric variation exhibited in these light-curves it will be necessary to distinguish and define, as far as we can, the more important circumstances which operate in producing the regular ebb and



Light Curve of *U Pegasi*. 1900 January 1.



Light Curve of *RR Centauri*. 1900 January 1.

flow of brightness represented in the light-curves under consideration, as well as in all light-curves of the same type.

(1) It seems reasonable to regard the major portion of the variation of both *U Pegasi* and *RR Centauri* as due to the eclipse of one star by its fellow.

If we consider the component bodies to move in a closed orbit, to be of regular and unchanging figure, then expressions may be readily deduced to exhibit the relation that exists between the symmetrical portion of an Algol star's variation and the chief elements of the system.

As the purpose of this paper is to deal with a wider extension of the problem than the simple determination of the elements of orbital movement, I may here just refer to the fact that a fairly full exposition of the relation connecting movement and variation is given in *Monthly Notices*, vol. lxiii. pp. 531–534. Those curious regarding the preliminary portion of the present investigation are referred to this article.

(2) The formulæ given in *Monthly Notices*, vol. lxiii. p. 534, presume that the eccentricity of the system is zero.

In order to correct any error arising from this assumption it is necessary to introduce into the equations defining the variation terms depending on the eccentricity.

Let

P = Period of variable in minutes.

ε = Eccentricity of orbit.

λ = Longitude of periastron reckoned from line of sight.

θ = True angular distance of eclipsing star from line of sight at time T.

Δm = Change in magnitude per minute at time T.

Then it is evident that

$$\frac{P \cdot \varepsilon}{\pi} \sin(\theta+\lambda) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

expresses the difference (in minutes) between the true anomaly and the mean anomaly at any time T if the eccentricity be small.

Consequently

$$\frac{\Delta m \cdot P \cdot \varepsilon}{\pi} \sin(\theta+\lambda) \ldots \quad \ldots \quad \ldots \quad (2)$$

is the correction in magnitude to be applied to the mean places, computed on the basis of a circular orbit, to reduce them to true places.

Putting

$$\varepsilon \sin\lambda = p$$

$$\varepsilon \cos\lambda = q$$

expression (2) becomes

$$\left(\frac{\Delta m \cdot P}{\pi} \cdot \cos\theta\right) p + \left(\frac{\Delta m \cdot P}{\pi} \sin\theta\right) q \quad \ldots \quad \ldots \quad (3)$$

In the case therefore of the eccentricity and the position of the apsidal line being unknown, the above expression (3) will afford a means of determining their values.

(3) An examination of the light-curves of *U Pegasi* and *RR Centauri*, given above, indicates that eclipse alone will not account for all the phenomena of variation.

For example, we have distinct evidence in the case of both *U Pegasi* and *RR Centauri* of two unequal maxima.

This, as well as certain other irregularities, can be explained readily on the assumption that the eccentric movement of the component stars produces tidal perturbations, and consequent change of figure.

Physical movements of this nature must of necessity produce a measurable variation in the intrinsic brightness of the stars, as well as a definite and rhythmic alteration in their form.

If we regard these changes to be completed in the period of the star then a simple expression of the type

$$g \sin (\theta + Z)$$

may be taken as covering all the outstanding periodic variation due to physical causes.

Putting

$$g \sin Z = r$$
$$g \cos Z = s$$

this further correction becomes

$$r \cos \theta + s \sin \theta \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

(4) We still have the effect of the measurable velocity of light to consider. Theoretically this correction always remains to be made when the component stars of a binary system mutually eclipse one another. The correction admits of very simple exposition

Let

l = Time (in minutes) that light takes to cross the semi-orbit.

θ = Distance from line of sight.

Δm = Change in magnitude per minute.

Then correction for light equation becomes

$$\Delta m \,.\, l \,.\, \cos \theta \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

$\cos \theta$ being always positive.

This expression (5) gives the aberration in brightness in all Algol or eclipse light-curves, due to the apparent acceleration in time of the various phenomena of variation.

It is evident that if the amount of errancy be known, then the dimensions of the orbit are forthwith also known.

(5) It remains only to introduce a term, Δt, as a correction to the assumed time of passing the principal minimum phase.

If now we have computed the amount of symmetrical variation due to eclipse solely, it is clear that the residuals

$$(O - C)$$

representing for the most part unsymmetrical variation, must to a considerable extent be accounted for by the expressions set forth in paragraphs (2), (3), (4), and (5).

Grouping these expressions together we have the following typical equation :

$$\left(\frac{\Delta m \,.\, \mathrm{P}}{\pi} \cos\theta\right)p + \left(\frac{\Delta m \,.\, \mathrm{P}}{2\pi} \sin\theta\right)q + \cos\theta,\, r$$
$$+ \sin\theta,\, s + (\Delta m \,.\, \cos\theta)\, l + \Delta m \,.\, \Delta t = (\mathrm{O}-\mathrm{C}) \quad \ldots \quad (6)$$

where p, q, r, s, l, and Δt are unknown quantities.

III. *Size of U Pegasi.*

The high accuracy of the Harvard series of observations of *U Pegasi*, the many questions of extreme interest that arose out of even the seemingly unimportant features of Algol variation, as well as the desire to obtain confidence in any results that may emerge out of the present investigation, impel me to deal more fully with the measures of this star than I would otherwise.

I accordingly give in full detail the Harvard observations of *U Pegasi*.

Col. (1) gives the date of observation ; col. (2) these dates reduced to the mean light-curve of 1900 January 1, the period used in this reduction being

$$8^{\mathrm{h}}\ 59^{\mathrm{m}}\ 41^{\mathrm{s}}\cdot 34$$

while col. (3) gives the magnitudes corresponding to the dates in col. (1).

TABLE I.

Observations of U Pegasi.

No.	Date. 1895.	Red. Date H.M.T. 1900.	Magnitude.	No.	Date. 1895.	Red. Date H.M.T. 1900.	Magnitude.
1	Nov. 16·464	Jan. 1·100	9·60	13	Nov. 30·563	Jan. 1·331	9·37
2	·481	·117	·40	14	·572	·340	·20
3	·494	·130	·44	15	·583	·351	·24
4	·503	·139	·36	16	·594	·362	·37
5	·508	·144	·23	17	·615	·008	·58
6	·520	·156	·26	18	·631	·024	·50
7	·531	167	·33	19	·639	·032	·47
8	·544	·180	·48	20	·647	·040	·82
9	·556	·192	·50	21	·658	·051	·80
10	·576	·212	·65	22	·667	·060	·63
11	·599	·235	·85	23	·682	·075	·58
12	30·553	·321	·30	24	·690	·083	·57

No.	Date.	Red. Date H.M.T. 1900.	Magnitude.
	1895.		
25	Nov. 30·706	Jan. 1·099	9·50
26	Nov. 30·715	·108	·36
	1896.		
27	Feb. 25·499	·309	·33
28	·510	·320	·30
29	·515	·325	·28
30	25·521	·331	·22
	1897.		
31	Oct. 18·522	·187	9·50
32	·531	·196	·58
33	·537	·202	·60
34	·544	·209	·70
35	·552	·217	·76
36	·559	·224	·85
37	·570	·235	·90
38	·578	·243	·94
39	·587	·252	·86
40	·593	·258	·63
41	·600	·265	·64
42	·607	·272	·51
43	·618	·283	·48
44	·626	·291	·38
45	·634	·299	·40
46	·645	·310	·30
47	·653	·318	·26
48	·660	·325	·25
49	·668	·333	·38
50	·678	·343	·32
51	·685	·350	·30
52	·690	·355	·38
53	·700	·365	·40
54	·706	·371	·40
55	·715	·005	·42
56	·724	·014	·53
57	·729	·019	·56
58	·734	·024	·62
59	·740	·030	·66
60	·744	·034	·69
61	·749	·039	·74
62	·753	·043	·72

No.	Date.	Ref. Date H.M.T. 1900.	Magnitude.
	1897.		
63	Oct. 18·569	Jan. 1·367	9·36
64	·578	·001	·36
65	·583	·006	·45
66	·589	·012	·48
67	·595	·018	·49
68	·601	·024	·62
69	·608	·031	·65
70	·613	·036	·77
71	·619	·042	·74
72	·626	·049	·71
73	·631	·054	·72
74	·639	·062	·70
75	·647	·070	·58
76	·653	·076	·58
77	·659	·082	·50
78	·665	·088	·50
79	·672	·095	·42
80	·678	·101	·36
81	Oct. 18·684	·107	·35
82	Dec. 28·435	·262	·65
83	·440	·267	·58
84	·446	·273	·54
85	·455	·282	·50
86	·462	·289	·45
87	·467	·294	·38
88	·480	·307	·34
89	·486	·313	·35
90	·492	·319	·32
91	·497	·324	·29
92	·518	·345	·32
93	·523	·350	·30
94	·528	·355	·34
95	·535	·362	·38
96	·553	·005	·45
97	·560	·012	·48
98	·567	·019	·58
99	·576	·028	·62
100	·583	·035	·69

No.	Date.	Ref. Date H.M.T.	Magnitude.
	1898.	1900.	
101	Dec. 28·596	Jan. 1·048	9·80
102	·600	·052	·79
103	·607	·059	·77
104	·613	·065	·77
105	·618	·070	·67
106	·630	·082	·58
107	·635	·087	·50
108	·640	·092	·44
109	·644	·096	·44
110	·648	·100	·44
111	·665	·117	·36
112	·669	·121	·39
113	·676	·128	·37
114	·681	·133	·40
115	28·687	·139	·36
116	30·608	·186	·44
117	·612	·190	·47
118	·618	·196	·50
119	·628	·206	·60
120	·635	·213	·64
121	·644	·222	·86
122	·655	·233	·90
123	·662	·240	·96
124	Dec. 30·668	·246	·90
	1898.		
125	Jan. 1·531	·235	·94
126	·537	·241	·88
127	·544	·248	·82
128	·551	·255	·73
129	·558	·262	·62
130	·571	·275	·48
131	·575	·279	·44
132	·580	·284	·46
133	·585	·289	·40
134	·591	·295	·42
135	·598	·302	·37
136	·603	·307	·32
137	·622	·326	·28
138	·626	·330	·31

No.	Date.	Ref. Date H.M.T.	Magnitude.
	1898.	1900.	
139	Jan. 1·630	Jan. 1·334	9·34
140	·642	·346	·32
141	·647	·351	·32
142	·653	·357	·32
143	1·658	·362	·28
144	3·549	·005	·44
145	·556	·012	·45
146	·562	·018	·50
147	·574	·030	·65
148	·580	·036	·69
149	·585	·041	·76
150	·592	·048	·79
151	·597	·053	·76
152	·601	·057	·80
153	·619	·075	·64
154	·624	·080	·59
155	·629	·085	·54
156	·633	·089	·52
157	·638	·094	·46
158	·642	·098	·44
159	·658	·114	·32
160	·665	·121	·40
161	3·671	·127	·30
162	5·525	·106	·40
163	·531	·112	·36
164	·537	·118	·37
165	·543	·124	·38
166	·549	·130	·36
167	·565	·146	·32
168	·570	·151	·34
169	·576	·156	·36
170	·581	·162	·35
171	·585	·166	·36
172	·603	·184	·45
173	·609	·190	·42
174	·614	·195	·48
175	·618	·199	·52
176	·636	·217	·72

No.	Date. 1898.	Ref. Date H.M.T. 1900.	Magnitude.	No.	Date. 1898.	Ref. Date H.M.T. 1900.	Magnitude.
177	Jan. 5·642	Jan. 1·223	9·86	191	Jan. 7·523	Jan. 1·230	9·85
178	5·649	·230	·84	192	·538	·245	·87
179	7·442	·149	·35	193	·547	·254	·78
180	·450	·157	·35	194	·558	·265	·66
181	·457	·164	·31	195	·567	·274	·54
182	·462	·169	·32	196	·574	·281	·50
183	·469	·176	·36	197	·583	·290	·46
184	·476	·183	·42	198	·590	·297	·37
185	·485	·192	·46	199	·598	·306	·37
186	·490	·197	·50	200	·607	·314	·38
187	·494	·201	·52	201	·613	·320	·38
188	·501	·208	·59	202	·621	·328	·40
189	·508	·215	·67	203	·626	·333	·38
190	·513	·220	·80	204	7·633	1·340	9·35

We now proceed to obtain the mean light-curve of *U Pegasi* from the foregoing 204 observations.

In Table II. we have in detail the operation of finding the forty mean places set forth in Table III.

It will be observed that two observations are excluded—viz. Nos. 1 and 19. These are so manifestly out of accord with the other measures that no good purpose would be served by retaining them.

Also the following corrections for second differences have been allowed for :—

Number Table III.	Mean Date. d	h	m	Mean Magnitude.	Correction for Second Diff.	Corrected Magnitude.
6	Jan. 1	0	59	9·756	+0·002	9·758
7		1	11	·778	·004	·782
8		1	21	·736	·002	·738
25		5	28	·860	·004	·864
26		5	42	·906	·010	·916
27	1	5	55	9·878	+0·004	9·882

The mean magnitudes in Table III. are therefore corrected for second differences.

TABLE II.

Determination of Mean Places of U Pegasi.

Jan. 1·001	9·36	Jan. 1·048	9·79	Jan. 1·099	9·50
·005	·45	·048	·80	·100	·44
·005	·44	·049	·71	(·100	·60)
·005	·42	·051	·80	·101	·36
·006	·45	·052	·79	·106	·40
·0044	·424	·0496	·778	·107	·35
·008	·58	·053	·76	·1026	·410
·012	·48	·054	·72	·108	·36
·012	·45	·057	·80	·112	·36
·012	·48	·059	·77	·114	·32
·014	·53	·060	·63	·117	·40
·0116	·504	·0566	·736	·117	·36
·018	·50	·062	·70	·1136	360
·018	·49	·065	·77	·118	·37
·019	·56	·070	·67	·121	·40
·019	·58	·070	·58	·121	·39
·024	·62	·075	·64	·124	·38
·0196	·550	·0684	·672	·127	·30
·024	·50	·075	·58	·1222	·368
·024	·62	·076	·58	·128	·37
·028	·62	·080	·59	·130	·44
·030	·65	·082	·58	·130	·36
·030	·66	·082	·50	·133	·40
·0272	·610	·0790	·566	·139	·36
·031	·65	·083	·57	·1320	·386
(·032	·47)	·085	·54	·139	·36
·034	·69	·087	·50	·144	·23
·035	·69	·088	·50	·146	·32
·036	·77	·089	·52	·149	·35
·036	·69	·0864	·526	·151	·34
·0344	·698	·092	·44	·1458	·320
·039	·74	·094	·46	·156	·26
·040	·82	·095	·42	·156	·36
·041	·76	·096	·44	·157	·35
·042	·74	·098	·44	·162	·35
·043	·72	·0950	·440	·164	·31
·0410	·756			·1590	·326

Jan. 1·166	9·36	Jan. 1·223	9·86	Jan. 1·283	9·48
·167	·33	·224	·85	·284	·46
·169	·32	·230	·84	·289	·45
·176	·36	·230	·85	·289	·40
·180	·48	·233	·90	·290	·46
·1716	·370	·2280	·869	·2870	·450
·183	·42	·235	·94	·291	·38
·184	·45	·235	·90	·294	·38
·186	·44	·235	·85	·295	·42
·187	·50	·240	·96	·297	·37
·190	·42	·241	·88	·299	·40
·1860	·446	·2372	·906	·2952	·390
·190	·47	·243	·94	·302	·37
·192	·50	·245	·87	·306	·37
·192	·46	·246	·90	·307	·34
·195	·48	·248	·82	·307	·32
·196	·50	·252	·86	·309	·33
·1930	·482	·2468	·878	·3062	·346
·196	·58	·254	·78	·310	·30
·197	·50	·255	·73	·313	·35
·199	·52	·258	·63	·314	·38
·201	·52	·262	·62	·318	·26
·202	·60	·262	·65	·319	·32
·1990	·544	·2582	·682	·3148	·322
·206	·60	·265	·64	·320	·30
·208	·59	·265	·66	·320	·38
·209	·70	·267	·58	·321	·30
·212	·65	·272	·51	·324	·29
·213	·64	·273	·54	·325	·28
·2096	·636	·2684	·586	·3220	·310
·216	·67	·274	·54	·325	·25
·217	·76	275	·48	·326	·28
·217	·72	·279	·44	·328	·40
·220	·80	·281	·50	·330	·31
·222	·86	·282	·50	·331	·37
·2184	·762	·2782	·492	·3280	·322

Jan.	1·331	9·22	
	·333	·38	
	·333	·38	
	·334	·34	
	·340	·35	
	·3342	·334	
	·340	·20	
	·343	·32	
	·345	·32	
	·346	·32	
	·350	·30	
	·3448	·292	
Jan.	1·350	9·30	
	·351	·24	
	·351	·32	
	·355	·38	
	·355	·34	
	·357	·32	
	·3532	·317	
	·362	·28	
	·362	·37	
	·362	·38	
	·365	·40	
	·367	·36	
	1·371	9·40	
	1·3648	9·365	

TABLE III.

Mean Light-curve of U Pegasi.

No.	Date. 1900. d	1900. d h m	Observed Mag. m	Computed Mag. m	(O−C.) m
1	Jan. 1·0044	Jan. 1 0 6	9·424	9·447	−0·023
2	·0116	0 17	·504	·500	+ ·004
3	·0196	0 28	·550	·562	− ·012
4	·0272	0 39	·610	·633	− ·023
5	·0344	0 50	·698	·704	− ·006
6	·0410	0 59	·758	·756	+ ·002
7	·0496	1 11	·782	·782	·000
8	·0566	1 21	·738	·764	− ·026
9	·0684	1 39	·672	·660	+ ·012
10	·0790	1 54	·566	·562	+ ·004
11	·0864	2 5	·526	·500	+ ·026
12	·0950	2 17	·440	·443	− ·003
13	·1026	2 28	·410	·400	+ ·010
14	·1136	2 44	·360	·358	+ ·002
15	·1222	2 56	·368	·337	+ ·031
16	·1320	3 10	·386	·323	+ ·063
17	·1458	3 30	·320	·320	·000
18	·1590	3 49	·326	·330	− ·004
19	·1716	4 7	·370	·361	+ ·009
20	·1860	4 28	·446	·431	+ ·015
21	·1930	4 38	·482	·481	+ ·001

No.	Date. 1900. d.	Date. 1900. d h m	Observed Mag. m	Computed Mag. m	(O−C.) m
22	Jan. 1·1990	Jan. 1 4 47	9·544	9·538	+0·006
23	·2096	5 2	·636	·650	− ·014
24	·2184	5 15	·762	·767	− ·005
25	·2280	5 28	·864	·874	− ·010
26	·2372	5 42	·916	·924	− ·008
27	·2468	5 55	·882	867	+ ·015
28	·2582	6 12	·682	·721	− ·039
29	·2684	6 27	·586	·595	− ·009
30	·2782	6 41	·492	·498	− ·006
31	·2870	6 53	·450	·435	+ ·015
32	·2952	7 5	·390	·390	·000
33	·3062	7 21	·346	·347	− ·001
34	·3148	7 33	·322	·330	− ·008
35	·3220	7 44	·310	·321	− ·011
36	·3280	7 52	·322	·320	+ ·002
37	·3342	8 1	·334	·320	+ ·014
38	·3448	8 17	·292	·327	− ·035
39	·3532	8 29	·317	·342	− ·025
40	1·3648	1 8 45	9·365	9·375	−0·010

Dealing with the foregoing mean magnitudes in the manner indicated in my paper on the orbit of *RR Centauri* (*Monthly Notices*, 1903 June), we obtain the following elements :

Period of *U Pegasi*	$8^h\ 59^m\ 41^s{\cdot}34$
Epoch of minimum	1900 Jan. $1^d\ 1^h\ 11^m$
Inclination of orbit	15° 20′
Prolateness of stars	0·46
Brightness of $\text{star}_{(1)}$	0·57
Brightness of $\text{star}_{(2)}$	0·43

The components are considered to be equal in size, and to revolve round one another, in contact, in a circular orbit.

Computed magnitudes based on the foregoing group of elements are given in col. 5 of Table III., and the residuals in the last column of the same table.

Now, as already stated, it is evident that (1) if the orbit of *U Pegasi* be eccentric, (2) if there be a rhythmic and physical fluctuation in brightness due to tidal deformation, and (3) if the acceleration of the two minima, due to the light-equation, be sufficiently great to be discernible, then the computed magnitudes require a further correction for these secondary causes of variation,

and the (O−C) quantities of col. 6, Table III., yield data for determining the value and extent of these corrections.

Equation (6) expresses the relation which may reasonably be held to exist between the secondary causes of variation and the outstanding unsymmetrical portion of the light changes.

Recasting equation (6), so as to render it more uniform and serviceable, we may write it thus :

$$(10{,}000\ \Delta m \cos\theta)\frac{Pp}{10\pi} + (10{,}000\ \Delta m \sin\theta)\frac{Pq}{10\pi}$$

$$+(100\cos\theta)\,10r + (100\sin\theta)\,10s$$

$$+(10{,}000\ \Delta m\cos\theta)\frac{l}{10} + (10{,}000\ \Delta m)\frac{\Delta t}{10} = 1000\,(O-C) \quad \ldots\ (7)$$

We can now from Table III. readily form a system of equations of condition which determine (1) the amount of eccentricity of orbit, (2) any intrinsic changes in the brightness of the system, and (3) the absolute dimensions of the system.

System of Equations of Condition.

$$+31\left(\frac{Pp}{10\pi}\right) - 29\left(\frac{Pq}{10\pi}\right) + 73(10r) - 68(10s) + 31\left(\frac{l}{10}\right) + 43\left(\frac{\Delta t}{10}\right) = -23$$

42	31	81	59	42	52	+ 4
53	29	88	48	53	60	−12
62	24	93	36	62	67	−23
58	15	97	25	58	60	− 6
+47	7	99	−14	+47	+47	+ 2
00	0	100	0	0	0	0
−33	4	99	+12	−33	−33	−26
63	21	95	31	63	66	+12
53	29	88	48	53	60	+ 4
42	30	81	58	42	52	+26
32	30	72	69	32	44	− 3
21	26	63	78	21	33	+10
10	18	47	88	10	20	+ 2
4	12	34	94	4	13	+31
1	− 6	+19	98	− 1	− 6	+63
0	0	− 5	100	0	0	0
3	+10	26	97	+ 3	+10	− 4
11	21	46	89	11	23	+ 9
24	27	66	75	24	36	+15
−39	+36	−74	+67	+39	+53	= + 1

$$+31\left(\frac{Pp}{10\pi}\right)-29\left(\frac{Pq}{10\pi}\right)+73(10r)-68(10s)+31\left(\frac{l}{10}\right)+43\left(\frac{\Delta t}{10}\right)=-23$$

56	42	80	59	56	70	+ 6
75	37	90	44	75	83	−14
83	27	95	31	83	87	− 5
−65	10	99	+15	+65	+66	−10
+10	0	100	0	−10	−10	− 8
75	12	99	−16	75	76	+15
87	33	94	35	87	93	−39
63	37	86	50	63	73	− 9
46	38	77	64	46	60	− 6
31	34	67	74	31	46	+15
19	28	56	83	19	33	0
8	19	39	92	8	20	− 1
3	10	26	97	3	10	− 8
1	+ 6	14	99	− 1	− 6	−11
0	0	− 4	100	0	0	+ 2
0	0	+ 6	100	0	0	+14
2	−10	24	97	+ 2	+10	−35
8	19	37	93	8	20	−25
+20	−30	+54	−84	+20	+36	=−10

The normal equations resulting from the foregoing system of forty equations of condition are :

$$509\left(\frac{Pp}{10\pi}\right)$$

$$-2334\left(\frac{Pq}{10\pi}\right)+7710(10r)-57844(10s)-16241\left(\frac{l}{10}\right)-17959\left(\frac{\Delta t}{10}\right)=-11202$$

21911	−57014	− 1120	− 920	− 1411	− 570
	106371	+ 1570	+ 4730	+ 5220	+ 900
		193605	+ 4662	+ 5431	+22275
			69509	+78719	− 3370
				91269	=− 5020

which yield

$$\frac{Pp}{10\pi}=-0{\cdot}107$$

$$\frac{Pq}{10\pi}=+0{\cdot}000$$

$$10r=+0{\cdot}018$$

$$10s = +0{\cdot}085$$
$$\frac{l}{10} = +0{\cdot}585$$
$$\frac{\Delta t}{10} = -0{\cdot}587$$

From which, since

$$\frac{P}{10\pi} = 172$$
$$p = \varepsilon \sin \lambda$$
$$q = \varepsilon \cos \lambda$$
$$r = g \sin Z$$
$$s = g \cos Z$$

it follows that

$$\varepsilon = 0{\cdot}006$$
$$\lambda = 270^\circ$$
$$g = {\cdot}009$$
$$Z = 12^\circ$$
$$\Delta t = -5^{m}{\cdot}9$$
$$l = +5^{m}{\cdot}9$$

The purpose of the present paper is fulfilled in dealing only with the last of the foregoing values, viz.

$$l = 5^{m}{\cdot}9$$

This represents the time light takes to cross the semi-orbit of *U Pegasi*.

Reducing the value to miles we obtain as the distance of the component stars that go to form the system *U Pegasi*

63,240,000 miles

As observations of *U Pegasi* multiply, and a more and more accurate mean light-curve is the result, this quantity may be corrected to no inconsiderable extent.

I think, however, the present investigation has demonstrated the possibility of obtaining the absolute dimensions of a rapidly varying binary star. This in itself is a matter of some importance.

IV. *Size of RR Centauri.*

In the *Monthly Notices*, vol. lxiii. pp. 538, 539, we find twenty-nine mean magnitudes of this star, as also the corresponding computed magnitudes, derived in the ordinary way from a system of orbital elements. We may treat the

residuals in the last column of the paper referred to in the same manner as we have done the residuals of *U Pegasi*. That is, we may endeavour to discover what portion of the outstanding residuals is due to (1) eccentricity of orbit, (2) intrinsic changes in the surface brightness of the component stars, (3) light-equation.

Taking, therefore, as our type of equation of condition expression (7) in the preceding part of this discussion, we may readily form the following system :

Equations of Condition.

$$+29\left(\frac{Pp}{10\pi}\right)-13\left(\frac{Pq}{10}\right)+92\,(10r)-39(10s)+29\left(\frac{l}{10}\right)+32\left(\frac{\Delta t}{10}\right)=+10$$

+20	4	98	−19	+20	20	− 7
− 6	0	100	+ 4	− 6	6	+ 6
24	6	97	24	24	25	0
29	14	90	43	29	32	− 9
25	19	79	61	25	31	−16
17	20	64	77	17	26	− 8
8	15	45	89	8	17	+18
3	10	25	97	− 3	10	+17
0	− 2	+ 2	100	0	− 2	− 6
1	+ 7	−16	99	+ 1	+ 7	−12
6	14	40	92	6	15	+22
13	19	58	82	13	23	− 1
21	18	75	86	21	28	+ 3
26	15	87	50	26	30	− 1
22	7	96	29	22	23	−13
− 5	0	100	+ 7	+ 5	+ 5	− 5
+17	2	99	−14	−17	−17	+ 6
25	8	95	30	25	26	+ 2
26	16	85	53	26	30	0
20	19	73	69	20	28	+ 3
11	18	54	84	11	21	+ 3
4	11	34	94	4	12	−15
1	+ 6	−15	99	− 1	− 6	−11
0	− 3	+ 8	100	0	+ 3	− 7
3	10	29	96	+3	11	− 8
9	17	48	88	9	19	+ 8
17	20	65	76	17	26	+ 6
+16	−19	+81	−58	+26	+32	= + 7

Normal equations

$$8696\left(\frac{Pp}{10\pi}\right) - 59\left(\frac{Pq}{10\pi}\right) - 1692(10r) - 21330(10s) + 776\left(\frac{l}{10}\right) + 894\left(\frac{\Delta t}{10}\right) = +$$

$$5036 \quad -21351 \quad + 124 \quad + 23 \quad + 0 \quad -$$

$$145870 \quad + 270 \quad + 336 \quad + 319 \quad +$$

$$144555 \quad -864 \quad - 1019 \quad +$$

$$8690 \quad + 10612 \quad +$$

$$13641 \quad = +$$

which yield

$$\frac{Pp}{10\pi} = +0{\cdot}316$$

$$\frac{Pq}{10\pi} = +0{\cdot}016$$

$$10r = +0{\cdot}013$$

$$10s = +0{\cdot}065$$

$$\frac{l}{10} = +0{\cdot}029$$

$$\frac{\Delta t}{10} = +0{\cdot}034$$

From which since

$$\frac{P}{10\pi} = 278$$

$$p = \varepsilon \sin \lambda$$

$$q = \varepsilon \cos \lambda$$

$$r = g \sin Z$$

$$s = g \cos Z$$

it follows that

$$\varepsilon = 0{\cdot}012$$

$$\lambda = 90^\circ$$

$$g = 0{\cdot}006$$

$$Z = 12^\circ$$

$$\Delta t = +0^m{\cdot}3$$

$$l = +0^m{\cdot}3$$

Dealing again only with the quantity

$$l = +0^m{\cdot}3$$

we obtain as the semi-orbit of *RR Centauri*

3,800,000 miles

I may mention that I have instituted a series of observations of this star with the express purpose of securing as accurate a determination as possible of the four cardinal points of variation.

As the orbit of the star has been demonstrated to be practically circular, the four dates—principal minimum, principal maximum, secondary minimum, secondary maximum—will yield accurate values of the dimensions of the system, inasmuch as—

(Duration of first quadrant + duration of third quadrant)
−(Duration of second quadrant + duration of fourth quadrant)
= four times the light-equation of the radius of the orbit.

Micrometrical Measures of Double Stars. (Third Series.)
By Rev. T. E. Espin.

The following list completes the measures obtained up to the end of 1905. The stars are all situated between +30° and +40°. Attention has mostly been given to stars neglected hitherto, and a large number of the stars noted as double in the Catalogues of the Astron. Gesellschaft were put on the working list. Subsequently Professor Burnham informed me that these are already sufficiently well cared for, and so only measures were continued where they had been already commenced.

Stars of Σ and OΣΣ.

No.	R.A. 1900 h	m	Dec. °	′	P. °	D. ″	Mags.		Nights.	Date.
OΣΣ 2 ...	0	26·2	+33	1	85·3	55·67			2	04·81
Σ 40 ...		29·8	36	16	315·1	11·29	7·1	8·4	3	04·86
OΣΣ 4 ...		31·5	33	10	173·9	36·11			1	04·80
Σ 62 ...		44·8	35	13	304·8	11·38	8·8	9·0	3	04·88
OΣΣ 11 ...	1	1·6	38	7	159·7	62·77	7·0	8·0	1	04·87
Σ 179 ...		47·3	36	50	159·1	3·29			3	05·88
Σ 434 ...	3	37·4	38	4	85·1	30·38	7·0	7·1	2	05·08
Σ 447 ...		41·4	38	3	167·6	27·39	7·0	9·2	2	05·08
Σ 1688 ...	12	48·8	38	31	343·9	14·08	...	...	2	05·29
Σ 1692 ...		51·4	38	51	228·0	19·81	...	...	3	05·31
Σ 1702 ...		53·9	38	50	83·0	35·23	...	...	2	05·29
OΣΣ 125...	13	42·7	39	2	237·5	71·08	5·0	8·5	2	05·39
Σ 1965 ...	15	35·6	36	58	303·1	6·37			2	05·38
Σ 1973 ...		42·7	36	45	322·6	30·44			2	05·38
Σ 2610 ..	14	55·4	+35	16	294·9 203·3	3·84 12·01	8·0	8·1 11·5	3	05·87

No.	R A. 1900 h	m	Dec. °	′	P. °	D. ″	Mags.		Nights.	Date.	
Σ 2876 ...	22	7·7	+37	9	67·5	11·68	...	...	4	04·91	
Σ 2882 ...		9·9	37	15	326·4	3·07	9·0	9·1	3	04·90	
Σ 2894 ...		14·5	37	16	193·9	15·38	6·5	8·0	2	04·89	
OΣΣ 243...	23	5·4	36	19	319·1	66·98	6·5	7·0	2	04·78	
Σ 3028 ...		33·6	34	29	201·9	17·13	6·5	9·5	2	05·05	
Σ 3050 ...		54·4	+33	10	216·4	2·61	...	...	2	05·05	
					h's Stars.						
h 624 ...	0	23·8	+33	20	347·0	15·28	8·9	11·2	2	05 40	
h 636 ...	1	8·8	30	0	287·5	20·08	7·2	11·0	2	04·78	
h 1081 ...		24·3	41	0	317·3	9·35	9·0	9·3	2	04·86	
h 1087 ...		31·4	38	31	73 5	11·37	9·0	10·0	3	04·83	
h 645 ...		46·8	30	58	103·5	7·54	8·0	10·5	2	04·78	
h 1097 ...		50·2	37	15	39·2	14 45	9·5	11·0	3	05·20	
h 1120 ...	2	29·2	39	13	90·9	17·32	7·0	11·5	2	05·94	
h 654 ...		38·0	34	42	44·6	36·76	7·5	11·0	2	04·82	
h 669 ...	3	48 1	35	1	262·6	12·04	9·0	9·2	1	04·87	
h 496 ...	11	16·1	37	21	328·9	28·28	9·0	9·8	2	05·24	
h 519 ...	12	25·5	36	41	4·7	19·84	9·1	9·3	2	05·29	
h 554 ...	14	28·3	35	11	294·4	12·05	9·2	9·5	2	05·38	AB
h 562 ...		55·7	35	30	309·7	24·36	7·5	11·5	2	05·38	(Σ 1900 rej.)
h 565 ...	15	0·0	33	57	104·6	33·19	8·1	10·5	2	05·38	
h 566 ...		5·1	33	26	286·0	23·89	8·4	9·9	2	05·41	(Σ 1913 rej.)
h 2786 ...		29·6	38	46	166·8	24·53	8·1	11·5	2	05·38	
h 1349 ...	18	45·1	33	12	81·0	22·08	8·0	11·6	2	04·71	
h 1414 ...	19	29·1	35	54	24·8	15·47	8·8	10·0	3	04·65	
h 1447 ...		47·9	33	49	333·9	18·95	7·5	11·8	3	04·61	AB
					85·6	22·30	C = 13·2		3	05·04	AC
h 1449 ...		49·2	32	47	284·0	7·80	9·0	12·2	2	04·72	
h 1471 ...	20	0·7	31	55	4·4	29·18	5·9	11·5	3	04·63	
h 1523 ...		25·5	40	40	349·4	14·07	9·0	9·4	2	04·77	*h* 357°·4
h 1526 ...		26·8	35	1	329·6	8·72	8·8	8·9	3	04·74	
h 1535 ...		29·3	33	2	246·3	15·86	8·0	13·5	2	05·91	A*a*(new)
					151·0	17·47	...	13·0	2	05·91	AB
					232·2	34·28	...	11·0	2	05·91	AC
h 609 ...		29·5	40	12	327·1	25·73	8·7	8·9	2	04·71	
h 612 ...		37·3	38	44	8·8	47·97	6·5	11·5	3	04·71	
h 1560 ...		37·9	+35	33	246·2	11·13	9·0	11·5	2	05·93	AB
					74·3	24·98	...	13·0	2	05·93	AC

No.	R.A. 1900 h m	Dec. ° ′	P. °	D. ″	Mags.		Nights.	Date.
h 1568 ...	0 39·0	+35 34	43·8	11·19	8·7	11·5	2	05·93
h 1582 ...	45·9	38 9	45·0	17·13	7·8	13·0	2	05·89 AB(new)
			327·4	27·22	...	11·0	3	05·92 AC
h 1586 ...	48·3	35 21	260·9	15·62	7·8	12·7	2	04·71
h 1596 ...	51·8	33 39	295·5	16·86	8·9	11·2	3	04 68 *h* 258°·6
h 1664 ...	21 31·7	32 52	88·1	7·68	9·7	9·7	2	05·30
h 953 ...	22 0·1	32 27	104·4	21·14	6·8	12·5	2	04·66
h 1756 ...	17·5	30 10	286·8	21·54	7·0	11·7	3	04·76
h 965 ...	24·6	34 0	140·8	29·78	8·4	9·2	3	04·74
h 1779 ...	28·0	33 42	217·2	21·31	7·8	9·2	2	04·69 *h* 244°·9
h 1788 ...	30·5	41 3	298·9	3·71	8·7	9·2	2	04 71
h 968 ...	35·0	36 22	109·1	4·42	8·3	8·8	3	04·74
h 969 ...	41·3	33 27	24·8	5·98	...	...	3	04·78
h 1813 ...	44·1	41 4	61·6	9·36	8·9	9·0	2	04·98
h 1817 ..	46·1	33 56	239·5	10·46	9·0	9·4	2	04·74 *h* 247°·5
h 1832 ...	52 6	38 8	73·8	10·97	8·8	9·2	2	04·68
h 983 ...	23 9·9	31 14	157·7	16·41	8·8	9·5	2	04·81
h 1882 ...	22·9	38 51	323·4	13·00	9·0	13·0	3	05·95 *h* 306°·0
h 987 ...	24·7	+31 40	280·5	12·62	8·8	11·7	2	05·93

Various Stars.

Σ 3064 rej.	0 3·2	+39 32	357·5	23·92	6·8	9·6	2	04·72
H*h* 6 ...	14·8	37 41	18·6	70·39	6·5	8·9	3	04·82
A.G.C. ...	1 9·0	40 30	43·2	6·62	8·8	10·0	2	04·86
Σ 181 rej....	48·7	37 42	124·8	26·53	8·5	9·2	2	04·86
A.G.C. ...	50·3	35 33	70·1	5·24	8·7	8·9	2	04·80
Ho. 10 ...	52·9	37 11	193·1	2·66	8·0	11 0	6	05·86
Σ 210 rej....	59·7	36 28	242·8	16·82	8·6	9·5	2	05·91
A.G.C. ...	2 34·8	34 24	288·1	9·96	9·0	9·2	1	04·87
A.G.C. ...	3 7·4	37 9	128·1	5·28	9·0	9·3	2	05·44
A.G.C. ...	9·1	38 18	246·0	9·46	8·5	8·8	1	05·77
Σ 1382 rej.	9 43·1	34 33	106·8	27·89	6·5	11·0	3	05·25
Holmes ..	17 52·1	39 31	99·7	5·30	8·6	9·2	2	04·61
Σ 2386 rej.	18 41·7	35 26	18·1	20·43	8·7	9·2	2	04·60
H*h* 583 ...	46·2	32 41	73·2	36·71	5·5	13·0	2	04·84(new)AB
			121·7	58·91	C=9·5		3	04·83 AC
A.G.C. ...	19 1·9	37 53	4·0	5·58	8·7	9·1	3	04·65
H*h* 608 ...	12·9	37 57	71·0	100·14	...	...	2	04·81 θ Lyræ
A.G.C. ...	31·0	35 5	278·9	11·42	9·0	9·8	3	04·76
A G.C. ..	32·4	+36 4	332·3	2·99	9·0	9·4	3	04·65

No.	R.A. 1900 h	m	Dec. °	′	P. °	D. ″	Mags.		Nights.	Date.
A.G.C. ...	0	39·5	+31	43	168·0	11·11	8·5	9·5	2	04·81
A.G.C. ...		39·7	34	36	158·3	5·29	9·1	9·3	3	04·75
A.G.C. ...		57·9	31	22	354·7	12·81	8·7	9·1	2	04·84
Espin 202 ..		58·6	35	2	221·8	10·92	8·8	13·0	2	05·63 A*a*
Σ 2638 rej.	20	5·3	33	22	74·7	16·67	8·0	9·1	2	04·71
Aitken 281		6·8	34	34	169·3	3·87	8·6	8·7	2	04·94
A.G.C. ...		15·6	36	16	117·6	9·48	8·7	8·9	2	04·68
A.G.C. ...		20·5	31	53	342·6	5·51	8·0	8·6	2	04·67
A.G.C. ...		22·5	37	8	287·8	5·24	9·0	9·2	3	04·74
A.G.C. ...		25·5	37	11	210·9	3·76	7·5	8·3	6	04·83 AB
					200·7	11·65	9·0	10·7	2	04·90 CD
					99·9	87·97	...	...	2	04·90 AC
A.G.C. ...		30·3	40	12	267·3	9·26	8·5	8·8	2	04·71
A.G.C. ...		34·5	30	47	153·6	3·74	8·0	9·0	2	05·38
A.G.C. ...		41·8	36	25	205·4	6·26	8·9	8·9	2	04·74
A.G.C. ...		42·9	32	30	86·7	10·89	7·8	8·5	1	04·82
A.G.C. ...		56·4	33	47	30·4	6·68	8·0	10·0	2	04·83
A.G.C. ...	21	4·4	40	30	107·1	5·33	8·9	9·2	3	04·68
A.G.C. ...		15·0	38	44	114·1	5·77	...	...	2	04·68
S 799 ...		39·3	37	49	60·0	152·74	...	...	1	05·90 AB
					248·5	30·76	C = 14·0		2	05·93 BC (new)
A.G.C. ...	22	5·9	31	11	178·4	10·15	9·0	10·0	3	04·56
Espin 216...		33·3	36	9	0·4	2·32	9·5	11·0	3	05·87 BC
					39·4	45·07	A = 8·5		1	05 75 AB
H*h* 771 ...		34·8	38	32	48·6	61·23	4·7	9·6	2	04·64
H*h* 772 ...		37·0	39	42	15·9	69·32	...	...	2	04 68
A.G.C. ...		40·7	39	30	192·2	14·14	9·0	10·5	2	04·76
Espin 217...		40·9	36	23	61·5	3·11	10·7	11·4	3	05·86
					295·1	74·16	A = 8·3		2	05·81
Hu. 782 ...		40·9	33	28	322·4	1·95	9·7	10·2	2	04·79
A.G.C. ...	23	20·7	32	53	230·5	3·05	8·8	10·2	3	04·78
Sh. 348 ...		49·9	31	17	329·0	36·98	8·0	9·5	2	04·70
A.G.C. ...		50·6	37	56	53·4	5·03	9·1	9·2	2	04·71
A.G.C ...		52·1	+37	17	316·6	1·98	9·2	9·3	4	04·74

Notes.

h 1097. *h*'s place agrees with B.D. + 37°·416, and this has been accordingly measured. *h*'s description is: "In Cluster VII. 32; no particulars."

h 1120. *h*'s angle 100°·0. *h* gives a third star, 320° ± 25″, which was seen on each night, but not measured.

h 654. B.D. + 34°·504 taken, from which *h*'s place differs by −1ᵐ 9ˢ in R.A.

h 1526. 1904 October 24 suspected A double. This is Ho. 760, who reverses the angle of AB, and had found the close pair earlier in the year.

h 1535. *h* gives AB 108° ± AC 240°·3. The great difference in *h*'s position and the nearer *comes* led me to suspect at first that he had observed some other star. Subsequently it seemed probable that the difference in position might be explained by giving A a P.M. of 0″·163 towards 38°·0. The faint *comes* "*a*" would then have been distant about 7″ at the time of *h*'s observation, and might easily be overlooked. Professor Bakhuyzen informs me that the results of the Leiden meridian observations show that A has a P.M. of 0″·168 towards 47° 30′. This would make "*a*" even closer at the time of *h*'s measures.

Various Stars.

H*h* 6. A star with large proper motion—according to Porter, 0″·314 at 202°·3.

Ho. 10. This is a difficult star to measure, but there is possibly some motion:

Ho. 1884·56	P = 198°·5	D = 2″·50
Ho. 1893·86	196·6	2·58

Σ 1382 rej. Four *comites*, according to *h*. A 13·5 mag., P about the same distance as AB.

Hu. 782. Found and measured before Professor Hussey's results reached me.

Sh. 358. No alteration since β's measures. Washburn Obs., vol. i., p. 157.

New Double Stars. By Rev. T. E. Espin.

No.	B.D.	R.A. 1900 h m	Dec. ° ′	P. °	D. ″	Mags.		Nights.	Date.	
222	+38°46	0 20·6	+38 14	152·5	5·30	8·6	9·5	2	05·89	
223	...	41·5	38 15	262·5	3·82	9·5	9·5	3	05·83	
224	37·130	41·8	38 5	344·8	10·56	8·6	13·7	2	05·86	
225	37·138	42·8	38 6	250·9	6·49	9·0	14	2	05·86	
226	38·144	49·9	38 27	282·4	6·10	9·0	12·5	2	05·79	
227	34·293	1 34·6	34 17	78·1	3·76	9·3	9·8	2	05·90	
228	...	51·0	37 30	9·5	3·51	9·7	9·7	3	05·79	
229	37·497	2 5·2	37 37	38·2	1·67	9·0	10·5	4	05·87	
230	...	8·2	37 40	301·6	2·86	9·3	9·9	4	05·87	
231	37·606	35·6	37 59	81·1	3·95	8·7	9·5	2	05·83	
232	39·654	46·6	39 29	188·8	2·30	8·7	9·6	2	05·94	
233	34·722	3 37·4	35 0	80 ±	4 ±	8·6	12·0		05·87	
234	33·710	39·0	33 34	*f*	5 ±	9·3	12·0		05·89	
235	34·732	41·4	34 44	271·3	2·5	12·0	12·0	1	05·89	BC
				227·1	35·01	A = 8·7		2	05·88	AB
236	34·744	44·0	34 22	352·8	4·96	9·3	9·6	3	05·90	
237	33·757	54·6	33 58	117·8	6·65	9·0	10·0	2	05·88	
238	34·809	59·4	34 22	*sf*	2 ±	9·3	9·5		05·94	

No.	B.D.	R.A. 1900	Dec.	P.	D.	Mags.	Nights.	Date.
	°	h m	° ′	°	″			
239	35·856	4 16·5	35 59	...	4±	9 0 12·0		05·87
240	39·1083	44·0	39 18	...	5±	9·5 11·0		05·79
241	36·3293	18 48·0	36 41	69·8	2·03	9·1 10·7	2	05·71
242	36·3730	19 46·4	36 28	22·1	2·22	9·5 10·0	2	05·85
243	34·3844	58·2	35 6	294·7	4·78	9·0 10 2	3	05·71
244	34·3934	20 10·6	35 7	129·6	40·72	7·5 11·5	2	05 69 AB
				14·1	5·00	C = 12 0	2	05·69 BC
				306·0	4·74	D = 13·2	2	05·69 CD
245	39·5215	26·5	39 47	160·3	4·76	9·4 9·5	2	05·79
246	38·4133	27·9	38 11	8·2	6·21	9·0 11·5	3	05·75 AB
				355·4	10·93	10·5	2	05·72 AC
247	36·41 .6	32·6	36 30	147·9	5·49	8·8 10·2	2	05·82
248	36·4173	36·1	36 42	2·0	5·50	9·0 13·0	3	05·94 (*comes* 14″·7 *nf*)
249	33·4031	44·0	34 2	22·3	5·41	9·0 10·0	2	05·80
250	36·4287	48·2	36 22	87·6	4·26	9·2 12·5	3	05·86
251	36·4352	54·8	36 21	142·9	6 32	8·7 9·3	2	05·88
252	36·4442	21 6·2	37 0	170·2	3·49	8·7 9·5	2	05·75
253	37·4207	6·7	37 12	22·3	3·46	8·9 9·6	2	05·75
254	37·4210	7·0	38 4	330·3	2·39	8·8 9·1	2	05·75
255	39·4473	7 1	40 7	33·0	4·89	8·9 11·7	3	05·84
256	39·4481	9·0	40 7	280·5	4·34	9·5 9·7	3	05·84
257	38·4397	9·1	38 32	323·1	5·80	8·0 12·0	2	05·91
258	35·4543	25·5	35 59	355·3	4·02	9·3 12·0	3	05·87 BC
				203·3	25·41	A = 9·0	1	05·83 AB
259	38·4522	28·2	38 22	321·9	2·80	9·2 9·5	2	05·93
260	38·4525	28·5	38 35	280·8	5·63	9·0 13·0	2	05·85
261	39·4695	48·2	39 52	162·5	4·67	9·2 9·2	1	05·96
262	36·4884	22 32·4	37 9	162·2	5·16	8·7 10·5	2	05·78
263	40·4860	32·4	40 38	245·8	9·30	8·9 14·0	3	05·84
264	40·4862	33·0	40 30	356·4	8·54	8·6 12·5	3	05·84
265	32·4501	39·3	33 6	1·4	8·49	8 8 9·3	3	05·93
266	39·4958	48·8	39 48	84·8	13·75	8·0 10 7	2	05·86
267	..	23 25·8	38 57	174·0	2·21	9·6 11·0	2	05·86
268	39·5161	41·9	39 59	266·3	4·23	8·5 10·0	2	05·79
...	40·5150	43·1	40 33	215·5	26·78	7·9 8·4	2	05·94
269	40·5153	44·0	40 46	216·3	6·64	8·8 11·0	2	05·79
				139·8	15 42	C = 13	2	05·79
...	40·5167	48·0	40 48	145·4	50·98	6·5 8·8	2	05·94

Notes.

224. Discordant angles.
225. Measures somewhat discordant, very difficult.
226. The same remarks apply to this star.
244. CD. The measures are little more than estimations.
248. Measures of angle discordant, the 14-mag. *comes* noted only on October 31.
260, 267. Measures discordant.
B.D. +40°·5150. A fine wide pair, not given in any catalogue of double stars so far as I am aware.
B.D. +40°·5167. Marked double in Argelander: A orange, B contrasted blue

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Erratum.

In the Greenwich Double Star measures given in the November number of the *Monthly Notices* (vol. lxvi. No. 1) the date at the head of the "Epoch" column on pp. 20–32 should be 1904.